UNITED STATES
AMLR ANTARCTIC MARINE LIVING RESOURCES PROGRAM

AMLR 1993/94 FIELD SEASON REPORT

Objectives, Accomplishments and Tentative Conclusions

Edited by
Jane Rosenberg

May 1994

ADMINISTRATIVE REPORT LJ-94-13

Southwest Fisheries Science Center
Antarctic Ecosystem Research Group

The U.S. Antarctic Marine Living Resources (AMLR) program provides information needed to formulate U.S. policy on the conservation and international management of resources living in the oceans surrounding Antarctica. The program advises the U.S. delegation to the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR), part of the Antarctic treaty system. The U.S. AMLR program is managed by the Antarctic Ecosystem Research Group located at the Southwest Fisheries Science Center in La Jolla.

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TABLE OF CONTENTS

BACKGROUND

The long-term objective of the U.S. Antarctic Marine Living Resources (AMLR) field research program is to describe the functional relationships between krill, their predators, and key environmental variables. The field program is based on two working hypotheses: (1) krill predators respond to changes in the availability of their food; and (2) the distribution of krill is affected by both physical and biological aspects of their habitat. In order to refine these hypotheses, a study area was designated in the vicinity of Elephant Island (Figure 1). A seasonal field camp was established at Seal Island, off the northwest coast of Elephant Island, where reproductive success and feeding ecology of breeding seals and penguins are monitored. A complementary series of shipboard observations were initiated to describe both within and between season variations in the distributions of nekton, zooplankton, phytoplankton, and water types in the study area. The Seal Island field camp is activated each season in early December and remains occupied through mid-March; shipboard research is conducted from early January through mid-March. In addition, research on the ecology of Adelie penguins is conducted at Palmer Station during each austral spring and summer.

SUMMARY OF 1994 RESULTS

Four shipboard surveys were conducted between mid-January and mid-March, 1994. Two major water types were identified: Drake Passage and Bransfield Strait. A prevailing southwest to northeast water flow across the entire AMLR study area was observed, although intensified flow was evident in several areas. Lowest phytoplankton biomass was observed in Drake Passage waters. Highest biomass was observed in Bransfield Strait waters, particularly during Leg II when it was four times higher than Leg I. Early in the season, the highest densities of krill were found north of King George Island; five weeks later highest densities were found north of Elephant Island. Preliminary estimates indicate that krill biomass in the Elephant Island area was very low this season; the krill density was approximately one-fifth of the 1990-1993 average density. The overall krill length frequency distribution and maturity stage composition during the large-area surveys reflected low recruitment from the last two year classes (1991/92 and 1992/93) and continued importance of the 1990/91 year class. As in 1993, salps were the dominant taxa in zooplankton samples, although their abundance decreased as the season advanced. Throughout the season, salps were more evenly distributed over the survey area than krill. On Seal Island, Antarctic fur seal pup production was slightly lower this year compared to last, but survivorship appeared to be higher. Growth indices indicated that female fur seals were able to adequately obtain prey to feed their offspring. Fur seal pup production throughout the Elephant Island area increased by 10% since the last census conducted in 1991/92. On Seal Island, the survival of chinstrap penguin chicks from egg through creche stage was the highest observed during the last 5 years, although fewer adults attempted to breed and total production decreased from last year. The number of macaroni penguins breeding on Seal Island was 8% higher than last year. At Palmer Station, chick production at 52 sample colonies decreased 10.3% from 1992/93, although breeding success observed at the Humble Island colony improved over 1992/93.

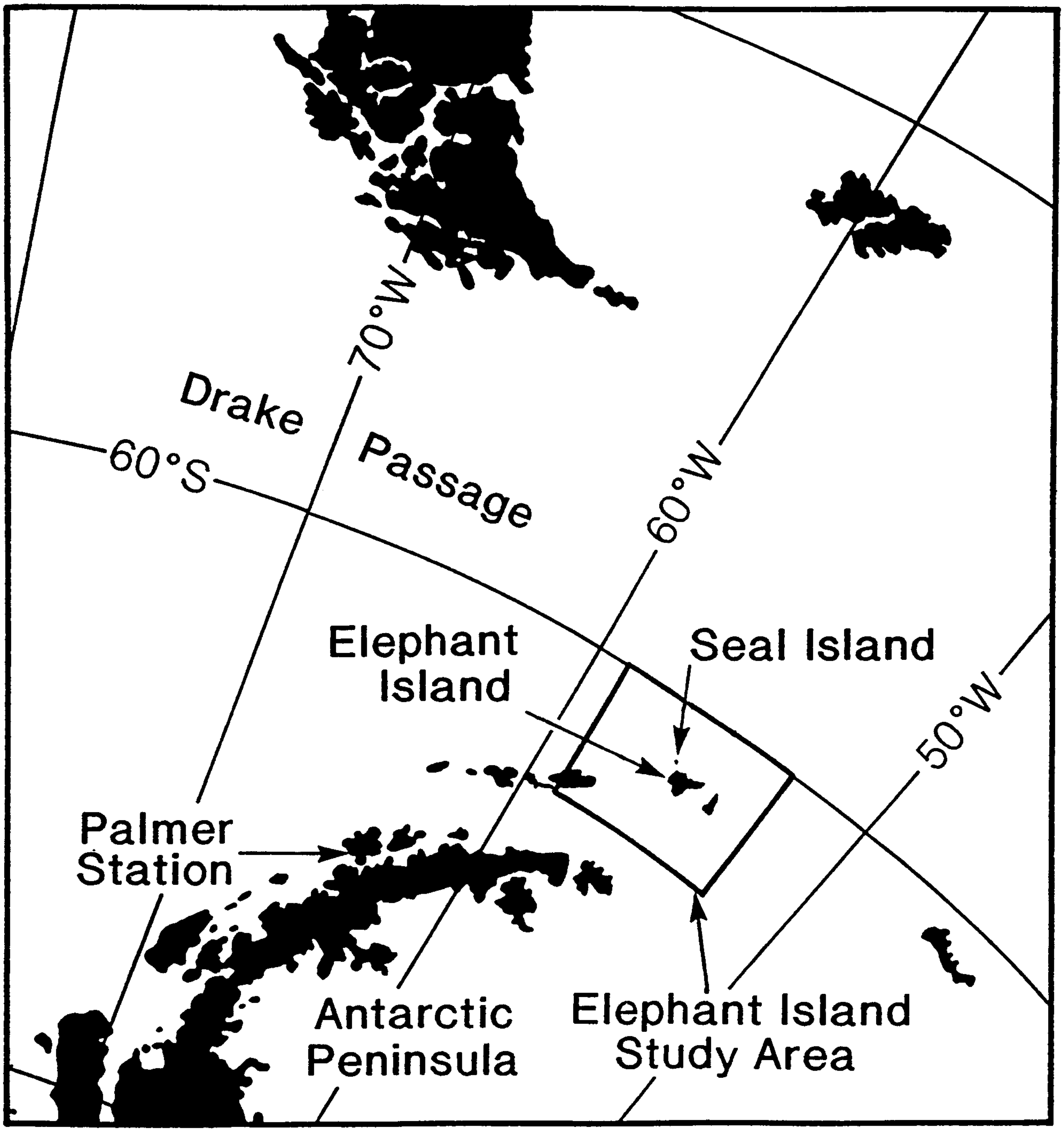

Figure 1. Locations of the U.S. AMLR field research program: Elephant Island Study Area, Seal Island, and Palmer Station.

OBJECTIVES

Shipboard Research:

1. Map meso-scale (10's to 100's of kilometers) features of water mass structure, phytoplankton biomass and productivity, and zooplankton constituents (including krill) in the area around Elephant Island.

2. Estimate the abundance of krill in the area around Elephant Island.

3. Delineate hydrographic and biological features along three transects: across the Bransfield Strait extending northwest of Nelson Island; across the shelf-break north of Elephant Island; and east of Elephant Island.

4. Map micro-scale (1 to 10's of kilometers) features of the distribution, density, and abundance of krill immediately north of Elephant Island, within the foraging range of krill predators breeding on Seal Island.

5. Describe the vertical and horizontal movement of krill swarms relative to the upper mixed layer of the ocean.

6. Conduct a fur seal survey at selected sites in the South Shetland Islands.

7. Calibrate an automatic direction finding (ADF) system located on Seal Island.

8. Provide logistical support to the Seal Island field camp.

9. Conduct seabird and marine mammal observations in the AMLR study area during Legs I and II, and correlate seabird and marine mammal abundance and distribution with aspects of their prey field. Also, conduct seabird and marine mammal observations during the northbound transit.

10. Calibrate acoustic transducers.

Land-based Research:

Seal Island

1. Monitor pup growth rates and adult female foraging of Antarctic fur seals according to CCAMLR Ecosystem Monitoring Program (CEMP) protocols.

2. Conduct directed research on pup production, female foraging behavior, diet, abundance, survival, and recruitment of fur seals.

3. Monitor the abundance of all other pinniped species ashore.

4. Deploy and calibrate an ADF system for determining the offshore foraging areas of fur seals and chinstrap penguins.

5. Conduct directed research on the predator-prey relationship between leopard seals and fur seals.

6. Monitor the breeding success, fledging weight, reproductive chronology, foraging behavior, diet, abundance, survival, and recruitment of chinstrap and macaroni penguins according to CEMP protocols.

7. Examine penguin chick growth and condition for intra- and inter-seasonal comparisons.

8. Conduct directed research on seasonal and diel patterns in the diving behavior of chinstrap penguins.

9. Assess the reproductive success, breeding chronology, survival, and recruitment of cape petrels.

10. Count Antarctic fur seals at known breeding colonies, and search for and identify newly-established or previously unknown fur seal colonies.

11. Resight tagged animals to better understand fur seal movements.

12. Describe and report marine debris sighted on beaches or on animals.

Palmer Station

1. Determine Adelie penguin breeding population size.

2. Determine Adelie penguin breeding success.

3. Obtain information on Adelie penguin diet composition and meal size.

4. Determine Adelie penguin chick weights at fledging.

5. Determine the amount of time breeding adult Adelie penguins need to procure food for their chicks.

6. Band a representative sample (1000 chicks) of the Adelie penguin chick population for demographic studies.

7. Determine adult Adelie penguin breeding chronology.

DESCRIPTION OF OPERATIONS

Shipboard Research:

Itinerary

Southbound Transit:	Depart Everett, WA	20 November 1993
	RITS Cruise	20 November - 06 January 1994
	Arrive Punta Arenas, Chile	07 January
Leg I:	Depart Punta Arenas	12 January
	Re-provision Seal Island	15 January
	Acoustic Transducer Calibration	16 January
	Survey A (first part)	17 - 28 January
	Survey B	29 January - 02 February
	Fur Seal Survey	02 - 04 February
	ADF Calibration	03 - 04 February
	Directed Sampling (MOCNESS)	04 - 06 February
	Call at Seal Island	04 February
	Cross-shelf Transect	05 February
	Survey A (second part)	06 February
	Arrive Punta Arenas	09 February
Leg II:	Depart Punta Arenas	14 February
	Re-provision Seal Island	17 February
	Survey C	17 - 19 February
	Directed Sampling (MOCNESS)	20 February
	Drogue Experiment	20 - 21 February
	Cross-shelf Transects	22 - 25 February
	Survey D (first part)	25 February - 08 March
	Acoustic Transducer Calibration	08 March
	Survey D (second part)	09 March
	Call at Seal Island	10 March
	Drogue Experiment	10 - 11 March
	East of Elephant Island Transect	12 March
	Arrive Punta Arenas	15 March
Northbound Transit:	Depart Punta Arenas	18 March
	SHOA Seabeam Survey	21 - 22 March
	Arrive Valparaiso	24 March
	Depart Valparaiso	27 March
	Arrive San Diego	12 April
	Depart San Diego	15 April
	Arrive Seattle, WA	25 April

Leg I.

1. *Surveyor* took her departure from Punta Arenas, Chile via the eastern end of the Strait of Magellan. Land fall was made at Seal Island, and all provisions and supplies were brought ashore to the AMLR field camp.

2. Three acoustic transducers were calibrated at Ezcurra Inlet, Admiralty Bay, King George Island. Two transducers, operating at 120kHz and 200kHz, were hull-mounted and down-looking. A third 120kHz transducer, housed in a dead-weight towed body, was side-looking. Standard spheres were positioned beneath the transducers via outriggers and monofilament line. The beam patterns were mapped, and system gains were determined for each of the transducers.

3. A large-area survey of 91 Conductivity-Temperature-Depth (CTD)/rosette and net sampling stations, separated by acoustic transects, was conducted in the vicinity of Elephant, Clarence, and the eastern end of King George Islands (Survey A, Stations A01-A91, Figure 2). Acoustic transects were conducted at 10 knots, using hull-mounted 120kHz and 200kHz down-looking transducers. Operations at each station included: (a) measurement of temperature, salinity, oxygen, light, transmissometer, and fluorescence profiles; (b) collection of discrete water samples at standard depths for analysis of chlorophyll-a content, particulate absorption spectra, particulate organic carbon and nitrogen concentrations, primary production, ATP content, size fractionation, floristics, and inorganic nutrient content; and (c) deployment of a Isaacs-Kidd Midwater Trawl (IKMT) to obtain samples of zooplankton and nekton. Due to adverse weather conditions, plankton nets were not towed at Stations A02, A71, and A84. In addition, poor weather caused operations to be halted at Station A85; the skipped stations (A85-A91) were completed at the end of the leg.

4. A small-area acoustic survey was conducted north of Elephant Island (Survey B, Figure 3). The survey was conducted at a ship's speed of approximately 5 knots, 24 hours per day over a 4-day period with no CTD/rosette or net sampling. Acoustic data were collected using the hull-mounted 120kHz and 200kHz down-looking transducers and a 120kHz side-looking transducer mounted in a towed body.

5. A census of fur seal breeding sites, including a survey for previously undescribed or newly colonized sites, was conducted along the coastlines of Elephant, Gibbs, Aspland, Eadie, Cornwallis and Seal Islands.

6. An automatic direction finding (ADF) system was calibrated by personnel on Seal Island. A floating sled, equipped with two radio transmitters, was towed behind *Surveyor* and signals were recorded by the system.

7. Directed MOCNESS sampling was conducted in areas of high krill concentrations north of Elephant Island; fine-scale acoustic data were collected concurrently during ten MOCNESS tows.

8. A series of CTD casts were made along a transect across the shelf-break north of Elephant Island (Stations X01-X07, Figure 4).

9. Continuous underway measurements of sea surface temperature, salinity, turbidity, chlorophyll fluorescence, air temperature, barometric pressure, relative humidity, wind speed and direction, and solar irradiance (ultraviolet, visible, and infrared) were recorded.

10. Observations of the distribution and abundance of seabirds and marine mammals were conducted.

Leg II.

1. *Surveyor* transited the same route as Leg I from Punta Arenas to Seal Island. A series of expendable bathythermographs (XBTs) were conducted while in transit across the Drake Passage by personnel from Chile's Servicio Hidrográfico y Oceanográfico de la Armada (SHOA). Fresh provisions and mail were transferred to the field camp at Seal Island.

2. A small-area acoustic survey was conducted north of Elephant Island (Survey C, Figure 3). The survey was conducted at a ship's speed of approximately 9 knots, 24 hours per day over a 3-day period with no CTD/rosette or net sampling. As on Leg I, acoustic data were collected using the hull-mounted 120kHz and 200kHz down-looking transducers and a 120kHz side-looking transducer mounted in a towed body.

3. Two MOCNESS tows were conducted in two areas of high krill density north of Elephant Island.

4. A drogue experiment was conducted to describe the vertical and horizontal movement of krill swarms relative to the upper mixed layer of the ocean. A small buoy, equipped with a radar reflector and drogue, was deployed for a 24-hour period, and side-looking and down-looking acoustic observations were made from the ship while transiting a survey pattern relative to the position of the buoy.

5. A transect across Bransfield Strait, extending northwest of Nelson Island, was conducted; the transect consisted of acoustic observations and fixed stations with CTD/rosette and net sampling operations (Stations X08-X21, Figure 4). The ship then transited to Elephant Island to conduct similar acoustic and sampling operations in a transect across the shelf-break north of the island (Stations X22-X29, Figure 4).

6. A large-area survey, similar to Survey A, was conducted around Elephant, Clarence, and the eastern end of King George Islands (Survey D, Stations D01-D91, Figure 2). Acoustic transects were again conducted at 10 knots, using the hull-mounted 120kHz and 200kHz down-looking transducers.

7. The hull-mounted 120kHz and 200kHz down-looking transducers were again calibrated in Ezcurra Inlet, Admiralty Bay, King George Island, using similar methods to the first calibration.

8. A second drogue experiment, similar to that conducted earlier in the leg, was conducted east of Seal Island.

9. A series of CTD casts were conducted along a transect east of the large-area survey grid (Stations X30-X37, Figure 4).

10. Continuous underway measurements were similar to those recorded during Leg I.

11. Observations of the distribution and abundance of seabirds and marine mammals were conducted.

Northbound Transit.

1. Observations of the distribution and abundance of seabirds and marine mammals were conducted.

2. A Seabeam survey of the Canon de Chacao, near Isla Chiloe, Chile, was conducted by personnel from SHOA.

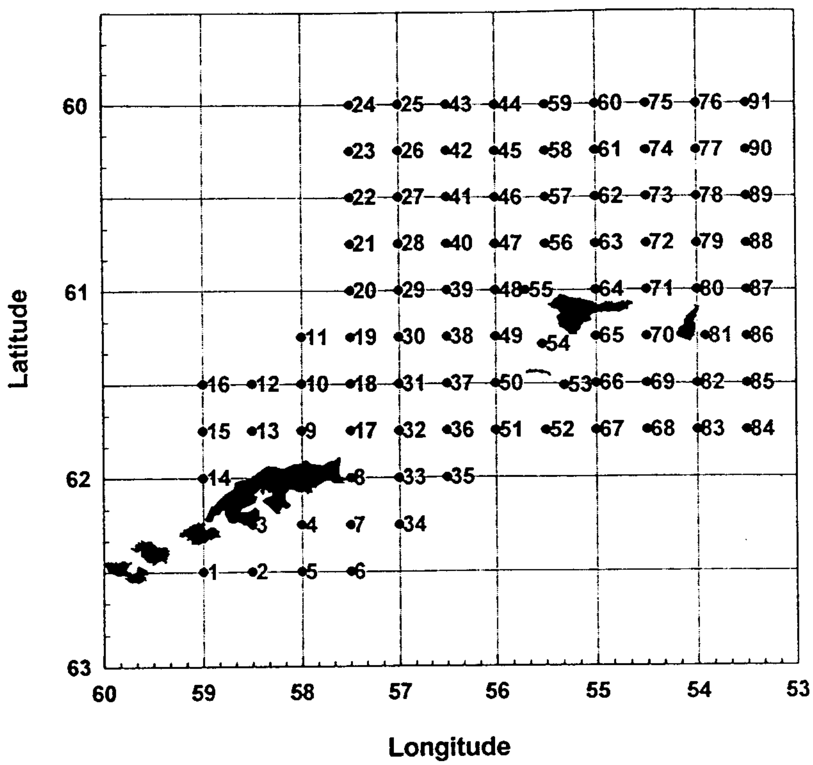

Figure 2. The large-area surveys for AMLR 94 (Surveys A and D).

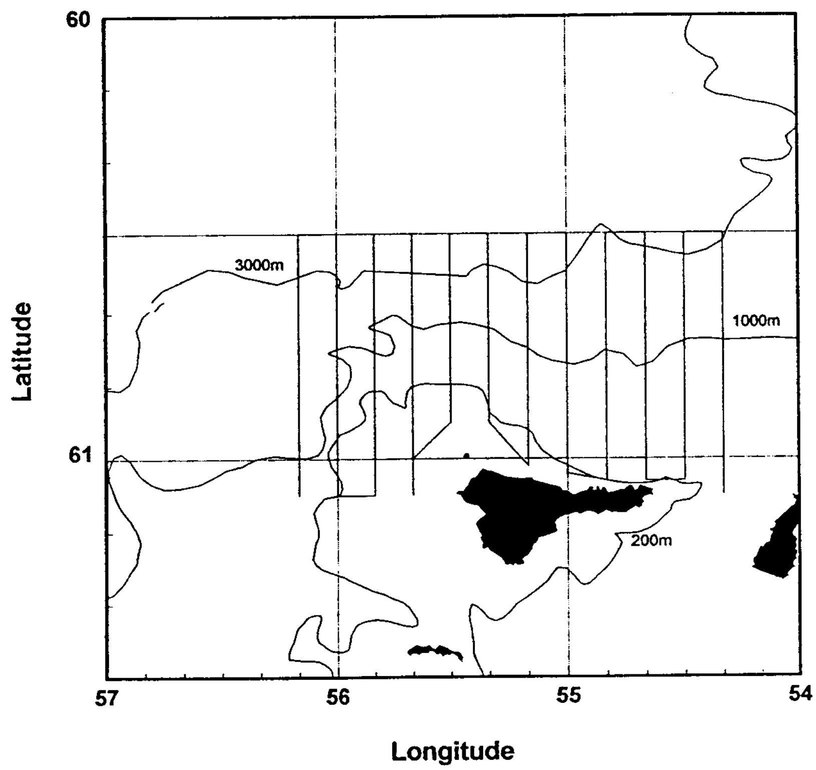

Figure 3. The small-area surveys for AMLR 94 (Surveys B and C).

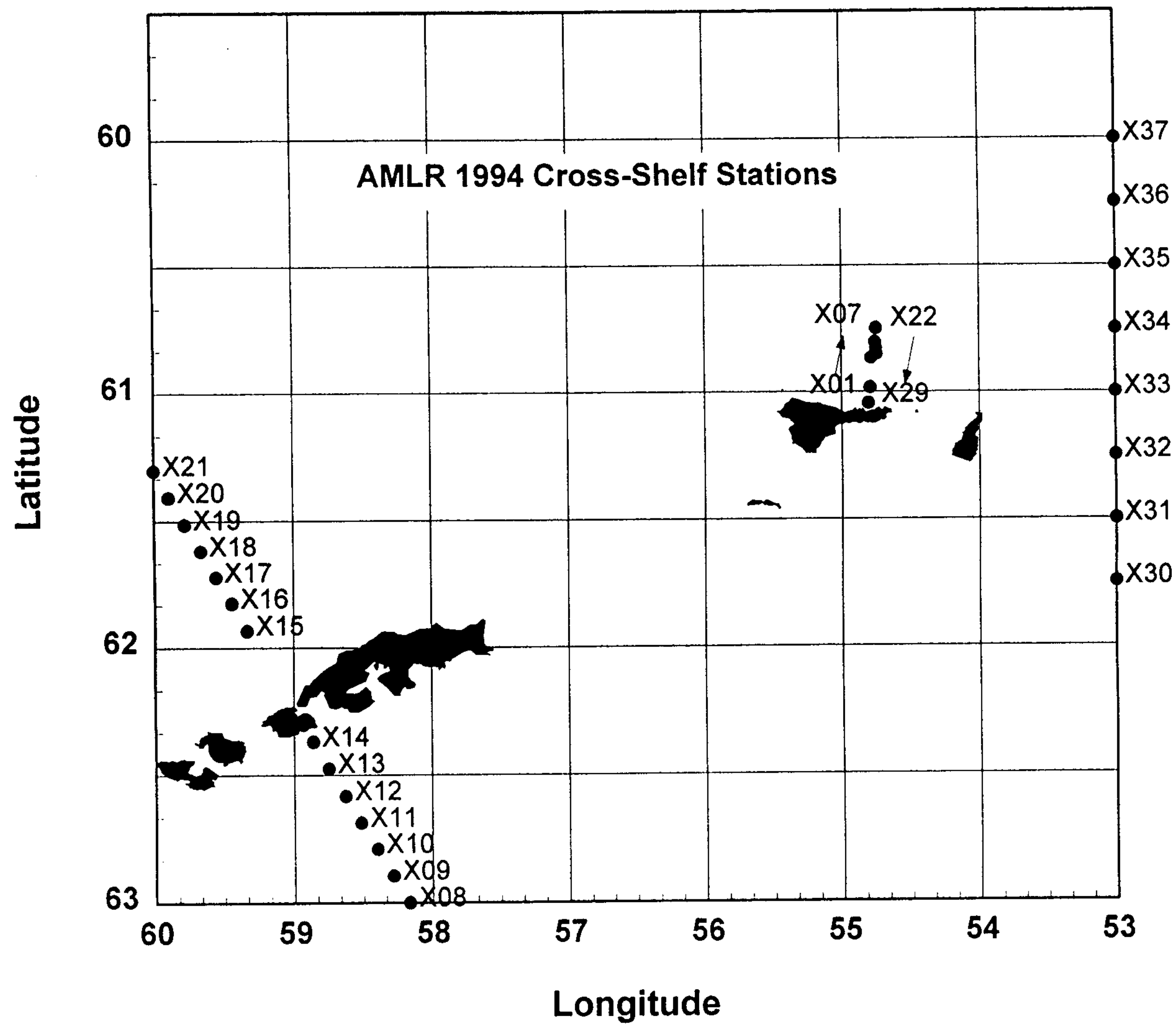

Figure 4. Transect across the shelf-break north of Elephant Island, Stations X01-X07 (Leg I) and X22-X29 (Leg II). Transect across Bransfield Strait, extending northwest of Nelson Island, Stations X08-X21 (Leg II). Transect east of the large-area survey grid, Stations X30-X37 (Leg II).

Land-based Research:

Seal Island

1. A five-person field team (P. Boveng, J. Jansen, W. Meyer, M. Schwartz, and B. Walker) arrived at Seal Island on 30 November 1993. The field team reactivated the field camp.

2. Radio transmitters were attached to 40 perinatal female fur seals in early December to measure durations of foraging trips. Twenty of these animals were also fitted with time-depth recorders (TDRs) to document dive characteristics and other foraging parameters. One female was instrumented with a special TDR designed to measure swimming velocity.

3. Fur seal pups were weighed at two-week intervals from late December through February. Pups (both alive and dead) were counted daily at the island's two main breeding colonies as well as a smaller colony. A census of the fur seal breeding colony on Large Leap Island was conducted in mid-January.

4. All classes of fur seals present on the island were censused at weekly intervals. Daily observations of tagged fur seals were made to assess survival, reproductive rates, and tag loss. Also, 19 new adult female seals and 198 pups were tagged this season.

5. Fur seal feces were collected during two-week periods for subsequent analysis of prey remains at National Marine Mammal Laboratory (NMML).

6. An ADF system was used to estimate the direction and distance of radio-tagged fur seals and penguins foraging within approximately 11 nautical miles (n.mi.) of Seal Island.

7. Weekly counts of other pinnipeds (Southern elephant seals, Weddell seals, and leopard seals) were conducted. Leopard seals were also opportunistically photographed and identified.

8. *Surveyor* called at the island on 15 January to offload fresh supplies and also to exchange personnel. M. Schwartz and B. Walker embarked the ship to assist with shipboard research during Leg I, while L. Hiruki disembarked to join the field team for the remainder of the season. B. Hancock (US Army Corps of Engineers) also arrived at the camp to conduct a geological hazard survey.

9. Penguin censuses, breeding success, and breeding chronology studies were begun in early December. Breeding success of chinstrap penguins was estimated by determining the number of chicks raised to the creche stage at designated nests in two study plots on the island. Macaroni penguin nests were also monitored.

10. A total of 40 adult chinstrap penguins were fitted with radio transmitters to monitor duration of foraging trips. Forty chinstrap penguins were instrumented with TDRs to provide information on diving behavior.

11. Forty stomach content samples of chinstrap penguins were collected to examine the relationship between available prey offshore and food brought back to the island to feed offspring.

12. The number of breeding pairs in all penguin colonies was counted after the completion of egg laying.

13. To estimate annual survivorship and recruitment into the breeding population, 2000 chinstrap and 84 macaroni penguin chicks were banded. Surveys to resight banded birds were conducted throughout the season.

14. The growth rates of chinstrap and macaroni penguins chicks were studied by measuring the weight, culmen length and depth, wing length, and noting the status of juvenile plumage.

15. Twenty-three cape petrel nests were monitored to determine breeding chronology. Three censuses were conducted of 65 cape petrel nests, and 45 chicks were banded and measured.

16. Prior to the end of Leg I, *Surveyor* called at Seal Island on 4 February to disembark M. Schwartz and B. Walker and pick up P. Boveng, J. Jansen, and B. Hancock for return to the United States. At the beginning of Leg II on 17 February, the ship visited again to deliver fresh supplies to the team.

17. Daily radio communications were maintained with Palmer Station until *Surveyor* arrived in the study area in mid-January. Communications were then maintained with *Surveyor*, M/V *Explorer*, R/V *James Clark Ross*, and biologists at various Antarctic science stations.

18. The field camp was closed on 10 March, and *Surveyor* recovered the field team for return to the United States.

Palmer Station

1. Field work at Palmer Station was initiated on 8 October 1993 and terminated on 1 April 1994.

2. One hundred Adelie penguin nests on Humble Island were observed from clutch initiation to creche to determine breeding success.

3. On 29 November, the number of breeding pairs at 54 sample colonies was counted during the peak egg-laying period.

4. The proportion of 1 and 2 chick broods was assessed at 49 colonies on 9 January. On 23 January, chick production was determined by censusing chicks at 52 colonies when approximately 2/3 of them were in the creche stage.

5. Fledging weights of Adelie penguin chicks were obtained at beaches near the Humble Island rookery.

6. One thousand Adelie penguin chicks were banded as part of continuing demographic studies on Humble Island.

7. Adult Adelie penguins were captured and lavaged (stomach pumping using water offloading method) for diet composition studies.

8. Thirty-three Adelie penguins breeding at the Humble Island rookery were fitted with radio transmitters; automatic data loggers recorded presence-absence data for these animals.

SCIENTIFIC PERSONNEL

Cruise Leader:
Rennie S. Holt, Southwest Fisheries Science Center (Leg I)
Roger P. Hewitt, Southwest Fisheries Science Center (Leg II)

Physical Oceanography:
Anthony F. Amos, University of Texas at Austin (Leg I)
Charles Rowe, University of Texas at Austin (Legs I and II)
Andrea Wickham, University of Texas at Austin (Legs I and II)
Samuel Hormazabal, Universidad Católica de Valparaiso, Chile (Leg II)

Phytoplankton/Primary Production:
Osmund Holm-Hansen, Scripps Institution of Oceanography (Leg II)
Walter Helbling, Scripps Institution of Oceanography (Leg I)
Virginia Villafañe, Scripps Institution of Oceanography (Leg I)
Humberto Diaz, Instituto Montemar, Chile (Legs I and II)
Marcel Ramos, Universidad Católica de Valparaiso, Chile (Legs I and II)
Pedro Baron, Universidad de la Patagonia, Argentina (Leg II)

Krill and Zooplankton Sampling:
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David Greene, Southwest Fisheries Science Center (Leg I)
Rick Phleger, San Diego State University (Leg I)
Volker Siegel, Sea Fisheries Research Institute (Leg I)
Alan Young, Moss Landing Marine Laboratories (Legs I and II)
Mike Force (RITS, Legs I and II, Northbound Transit)
Susan Kruse, Polaris Company (Leg II)
Jennifer L. Quan (Leg II)
Aaron Setran, U.S. Environmental Protection Agency (Leg II)
Peter Neville, Office of the Administrator, NOAA (Leg II, Northbound Transit)

Bioacoustic Survey:
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Girish Chandran, University of California at San Diego (Leg I)
Jay Kirsch, Chesapeake Biological Laboratory (Leg I)
Nick Carbone, Scripps Institution of Oceanography (Leg II)
Jane Rosenberg, Southwest Fisheries Science Center (Leg II)

Seabird and Marine Mammal Observations:
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Sophie Webb, Point Reyes Bird Observatory (Northbound Transit)

Drake Passage Thermal Structure and Hydrocarbons Sampling:
Christian Bonert Anwandter, Serv. Hydro. y Ocean. de la Armada, Chile (Leg II)

Seabeam Survey of Canon de Chacao:
Hernan Vergara, Serv. Hydro. y Ocean. de la Armada, Chile

Seal Island Field Team:
Peter Boveng, National Marine Mammal Laboratory
Lisa Hiruki, National Marine Mammal Laboratory
John Jansen, National Marine Mammal Laboratory
William Meyer, National Marine Mammal Laboratory
Michael Schwartz, National Marine Mammal Laboratory
Brian Walker, National Marine Mammal Laboratory
Bill Hancock, US Army Corps of Engineers

Palmer Station:
William Fraser, Montana State University
Donna Patterson, Montana State University

DETAILED REPORTS

1. Physical oceanography; submitted by Anthony F. Amos (Leg I), Charles Rowe (Legs I and II), Andrea Wickham (Legs I and II), and Samuel Hormazabal (Leg II).

1.1 Objectives: The physical oceanography component of the AMLR program provided the means to identify contributing water masses and environmental influences within the study area, as well as to log meteorological and sea surface conditions annotated by the ship's position. The instrumentation and data collection programs served as host to other scientific components of the program. AMLR 94 is the fifth field season for the collaboration of physical measurements with biological studies.

1.2 Accomplishments:

CTD/Rosette Stations: Ninety-seven CTD/rosette casts were made during Leg I, and 121 casts were made during Leg II. The majority of the casts occurred at the 91 stations of the large-area surveys, designated A01-A91 on Leg I and D01-D91 on Leg II. To further delineate hydrographic features, three additional transects of CTD stations were conducted: across the Bransfield Strait extending northwest of Nelson Island (Leg II); across the shelf-break north of Elephant Island (Legs I and II); and east of Elephant Island (Leg II). The transect east of Elephant Island expanded the large-area survey grid by eight extra stations. Some 2,290 water samples were collected from the rosette bottles. The samples were analyzed for micronutrient concentration, phytoplankton, and chlorophyll by the phytoplankton group, for salinity by *Surveyor's* Survey Technicians, and for dissolved oxygen by the physical oceanography team. Almost all samples were analyzed aboard for salinity using a Guildline Autosal to verify the depth that each bottle tripped and to provide calibration data for the CTD conductivity sensor.

Underway Environmental Observations: Twenty-nine and 28 days of continuously acquired weather, sea temperature, salinity, water clarity, chlorophyll, and solar radiation data were collected during Leg I and Leg II, respectively. Augmented with the ship's navigational information, these data provided complete coverage of surface environmental conditions encountered throughout the AMLR field season.

1.3 Methods:

CTD/Rosette: Water profiles were collected with a Sea-Bird model SBE-9 PLUS CTD/rosette. CTD profiles were limited to 750m depth (or to within a few meters of the ocean floor when the depth was 750m or less). A Benthos 12kHz pinger was attached to the rosette frame. A Sea-Bird dissolved oxygen sensor, Seatech 25cm beam transmissometer, Biospherical Instruments PAR sensor, and a Seatech *in situ* fluorometer (interfaced with the CTD) provided additional water-column data on each station. Downtrace and uptrace CTD data for each station were stored on Bernoulli disks; data were collected at 24 scans/second on the downtrace and 6 scans/second on the uptrace. All rosette bottles were fired during the upcast. Raw CTD data were corrected for time-constant differences in the primary and oxygen sensors. Parameters were then derived and binned by 1-meter averages for analysis. This year, an immediate sorted printout of the rosette bottle tripping sequence was devised so that sampling strategies could be adjusted immediately after the CTD was retrieved.

Underway Data: Data from various environmental sensors were collected, multiplexed, and combined with the GPS navigational information. A Data World computer equipped with a GTEK multiple serial port card was used to acquire, display, and store the data at one-minute intervals throughout the cruise. *Surveyor's* Electronic Technicians installed several RS-232 interfaces, allowing ASCII data to be sent from the ship's various systems to the Data World computer. Ship's position data were obtained using a Trimble NavPac II GPS system. Ship's course was acquired from the gyro compass; relative wind speed, direction, and air temperature from the R.M. Young weather system; and sea temperature and salinity from the Sea-Bird SBE-21 Thermosalinograph. Vertical depth data came from the center beam of the Seabeam system. Using a Weathermeasure signal-conditioning unit, barometric pressure, air temperature, and relative humidity data were sent to a Hewlett-Packard 3421A data acquisition unit, where they were multiplexed and sent to the Data World computer via an IEEE-488GPIB interface.

A single optical sensor (Biospherical Instruments PAR sensor) was mounted on the flying bridge to sense solar radiation relatively unobstructed by *Surveyor's* superstructure and masts. These data were fed directly to the HP multiplexer. Finally, a plumbed sea-water flow-through system provided bubble-free water for a Seatech 25cm transmissometer and a Turner Designs Fluorometer to monitor sea surface water clarity and chlorophyll fluorescence. The inputs were also fed to the HP 3421A. Throughout the cruise, a Hewlett-Packard 7475A plotter was used to provide real-time graphical representation of environmental conditions.

1.4 Results and Tentative Conclusions:

Oceanography: As in the past, we classified and grouped stations with similar vertical temperature/salinity (T/S) characteristics. We have identified five water types, designated I through V. It should be noted that these water types are based on T/S curves from the surface to 750m (or to the bottom in water shallower than 750m). For example, water type I has the following characteristics: warm, low salinity surface water; a strong sub-surface temperature minimum (called "Winter Water" at approximately -1°C, and a salinity of 34.0 ppt.); and a distinct T/S maximum near 500m (called "Circumpolar Deep Water" or CDW). We defined the oceanic water of the Drake Passage as water type I. In the Bransfield Strait and south of Elephant Island, water type IV dominated: bottom waters were around -1°C and the sub-surface extrema were far less prominent, although a slight "crook" in the curve was characteristic. In between, there were transition zones where adjacent water types mixed.

Figure 1.1a and 1.1b are composite T/S scatter diagrams for all stations of the large-area survey on Leg I and on Leg II, respectively. Also, the T/S curves for each station of the large-area survey on Leg I and Leg II have been plotted in Figures 1.2a and 1.2b, respectively. From these "worm" diagrams, two major water divisions can clearly be seen on both legs. A dotted line delineates the border of water type I from the other water types; boundaries between the other types have not been drawn to avoid confusion. Note that Figure 1.2b includes the eight extra CTD stations along the 53°W meridian. Figure 1.3 illustrates the five water types on separate panels with the heavy dark curve representing the T/S characteristic of the specific water type. These data have not been finalized and some editing is required. Two differences can be noted between this and last year's surveys: (1) sea surface temperatures in the Drake Passage were cooler in 1994 relative to 1993; and (2) Winter Water temperature minima (sub-surface) were warmer in 1994 as compared to 1993. Winter Water temperature minima for Leg I were around -1°C, compared to those last year at near -1.5°C. Leg II Winter Water temperature minima were well above -1°C this year, while in 1993 they were around -1.2°C.

The dynamic topography of the region is shown in Figure 1.4a and 1.4b. The implied flow at the surface relative to 500m is illustrated by streamlines with arrows pointing in the direction of flow. As usual, the major feature was the prevailing SW to NE flow across the entire AMLR study area. Like last year, this flow was intensified in three zones: north of Elephant Island, roughly following the topographic trend of the shelf-break; in a narrow band paralleling the northern boundary of the Bransfield Strait south of King George Island; and a more northerly trend between Elephant and Clarence Islands. Another intensification was seen north of King George Island. A dynamic topographic high occurred, similar to 1993, in the north of the AMLR study area near the 57°W longitude and shifted and weakened during Leg II. Streamlines of Leg II did not turn north above Clarence Island as they did for Leg I. Instead, the flow had a more easterly trend later in the season (Figure 1.4b). While the topographic slope was not as intense this year as last, considerable intensification occurred between Elephant and Clarence Islands. This was the boundary of a density front at the sea surface. The main axis of northward flow in the northeast corner was shifted well to the east compared to 1993. A similar pattern was revealed when the surface was referenced to 200m, so it is assumed that these patterns are reasonably representative of the mean flow in the upper water column. A suggestion of some return flow can be seen in the Bransfield Strait below Elephant and Clarence Islands during Leg II (Figure 1.4b).

The surface temperature (4m depth) and salinity fields for both legs are contoured in Figures 1.5 and 1.6. The 2°C contour was far to the north compared to AMLR 93, while surface water less than 0°C was found only in a small area east of Clarence Island and not at all on Leg II. An interesting hot spot (>1.9°C) was found southeast of King George Island in the Bransfield Strait. Surface salinity distribution was similar to that of Leg I in 1993, except that the high salinity water penetrated farther north of the islands than in the previous year. To illustrate the contrast between CDW and deep water south of the South Shetland Islands, Figure 1.7 shows the horizontal distribution of dissolved oxygen at 500m. CDW is depleted in oxygen following its long journey from the north, while the midwaters of the Bransfield Strait are oxygen-rich from their source nearby at the Antarctic sea surface. The easterly trend of the flow during February and March (Leg II) can be seen in all the parameters (Figures 1.5b, 1.6b, and 1.7b).

As in 1993, the sub-surface temperature minimum often coincided with a chlorophyll and oxygen maximum (see Phytoplankton report in this volume). The remnant of last winter's deep homogeneous surface layer retains its high oxygen content, while warming surface waters lose oxygen. The dissolved oxygen sensor gave consistent and reasonable values this year. Unfortunately, we were not able to confirm the absolute values due to problems with the Hach dissolved-oxygen analysis equipment that was used for the first time this year.

Meteorology: Similar to 1993, there were relatively few storms during AMLR 94, although the mean surface wind was more intense than last year. Although air temperatures were below freezing for only a few hours during Leg I, the overall air temperature was cooler and never approached the highs of near 6°C experienced during the large-area survey of 1993. This can probably be attributed to the lower sea surface temperatures of AMLR 94. The underway system was upgraded again this year. Modifications to the system included automatic calculation of times of sunrise, sunset and local apparent noon based on the ship's current position. When the predicted time of a solar event occurred, the screen and record were automatically marked with a comment listing local time, event, local date, and day of the week. The underway system also displayed a continuous update of the time and distance to the next station, and provided markings of the record at predetermined intervals for the bird surveys.

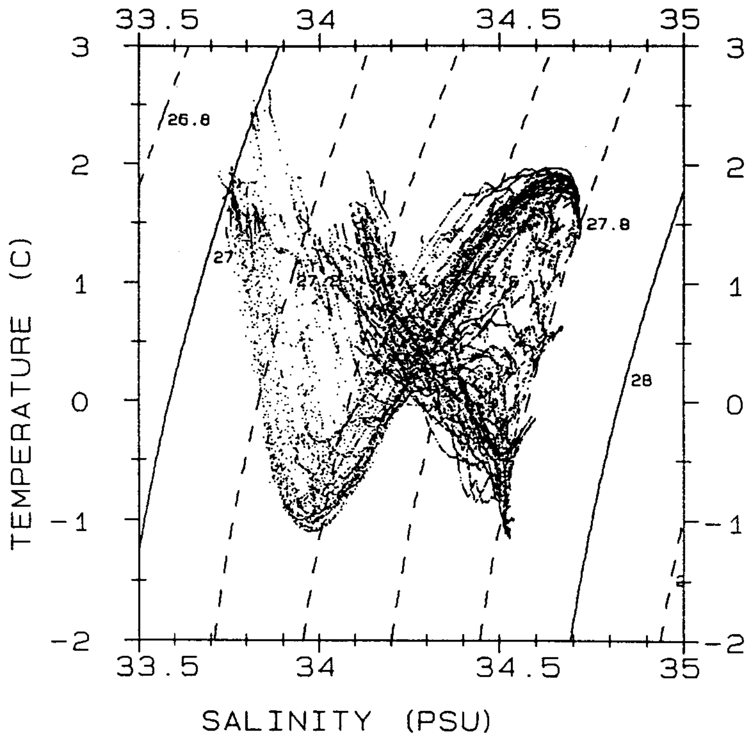
1.5 Disposition of Data: The CTD/rosette, underway, weather station and XBT data were stored on 44 Mbyte and 150 Mbyte Bernoulli disks. The raw data were taken to the University of Texas Marine Science Institute in Port Aransas, Texas; final analysis will be under the direction of Anthony F. Amos. Copies of the CTD/rosette 1-meter averages and modified 1-minute underway data have been distributed on diskettes to the phytoplankton and acoustics groups. Copies of the printed log sheets and plots were provided daily to the phytoplankton group and the bird and marine mammal observers. Special logs listing time, position and weather conditions for each scientific event were provided to the phytoplankton and zooplankton groups, and the bird and marine mammal observers.

1.6 Acknowledgments: Special mention goes to the Electronic Technicians; the survey department for setting up the CTD/rosette for each station, collecting water samples, and processing salinity samples; the winch operators for their expert handling of the CTD/rosette under assorted sea conditions; and the Ship's Officers for keeping station and on-deck coordination of operations. The new arrangement of table-tops, shelves, drawers, and cabinets in the after-chart room is excellent.

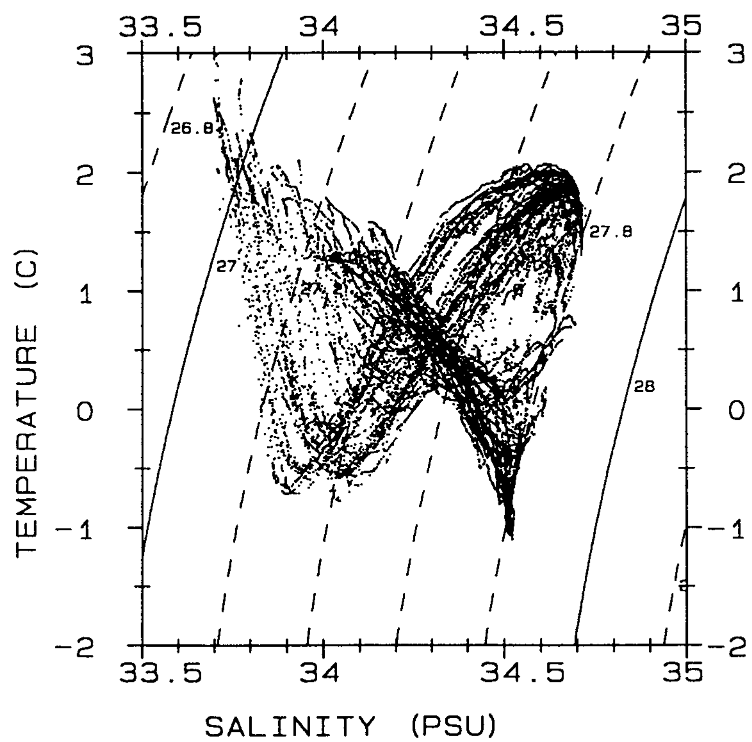
1.7 Problems and Suggestions: The requirement to secure the Seabeam system during major portions of the operations was at times inconvenient. Knowledge of vertical depth is useful for safely deploying the CTD in shallow water, and a continuous record of vertical depth is useful in describing topographically-controlled frontal features.

Some problems occurred with the rosette sampler. Bottles at times did not trip when triggered, and occasionally more than one bottle tripped at the same depth even though they were triggered at different levels. Some of the early problems were solved by adjusting bottle lanyards; however, much inter-parameter comparisons must be done to verify the proper sampling levels of all samples. This problem was compounded by a drift in the Guildline Autosal used to calibrate the CTD salinity sensor and validate the sample depth. Despite these problems, we were able to verify the depth of most samples. One solution would be to purchase the new Sea-Bird carousel sampler which electronically triggers each bottle independently of the others.

The communications between the chart room and the main deck, winch, and bridge need improvement; at times, we experienced difficulty hearing radio traffic.



(a)



(b)

Figure 1.1 Composite temperature/salinity (T/S) scatter diagrams for all stations of the large-area surveys. (a) Leg I, Survey A and (b) Leg II, Survey D.

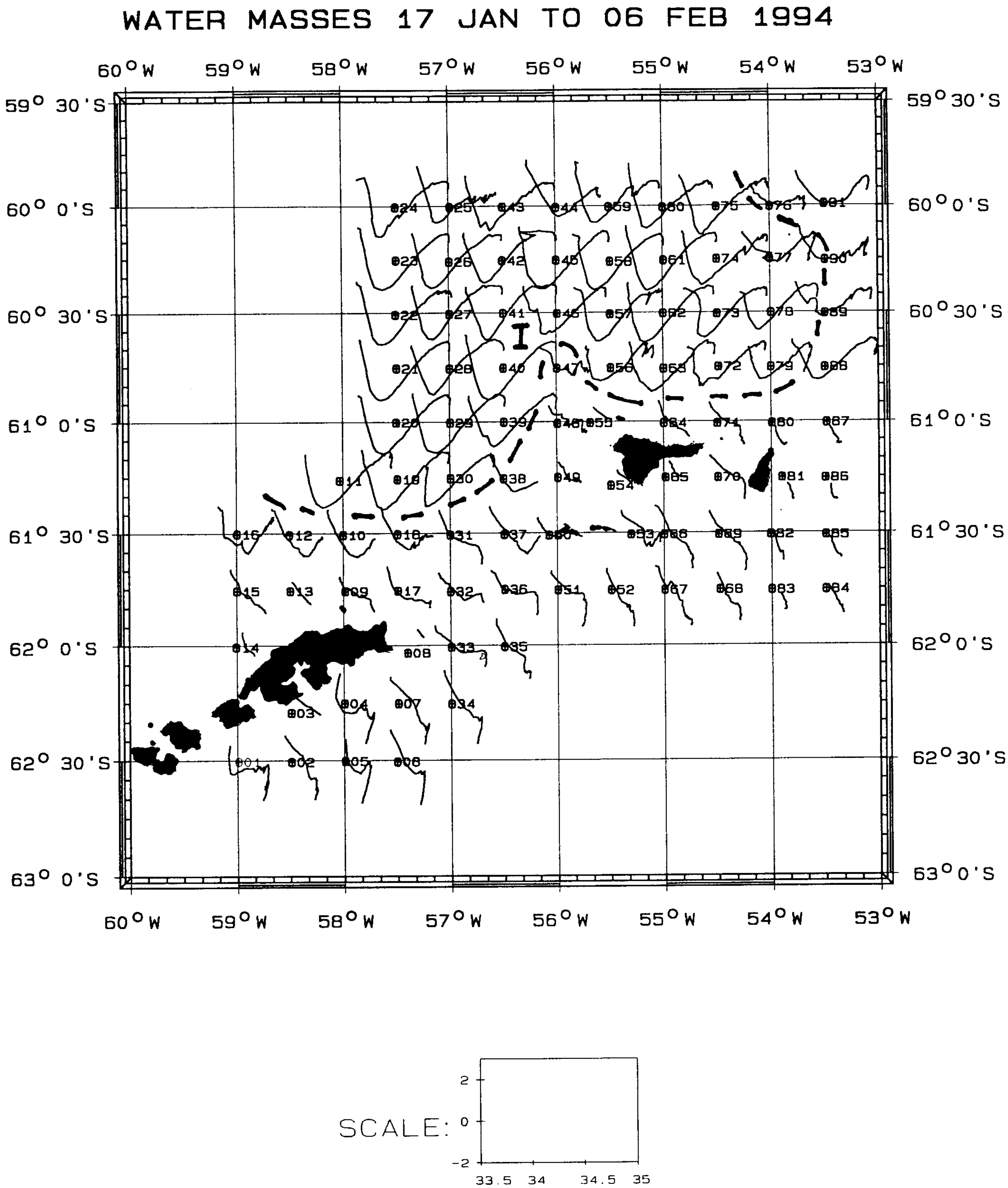
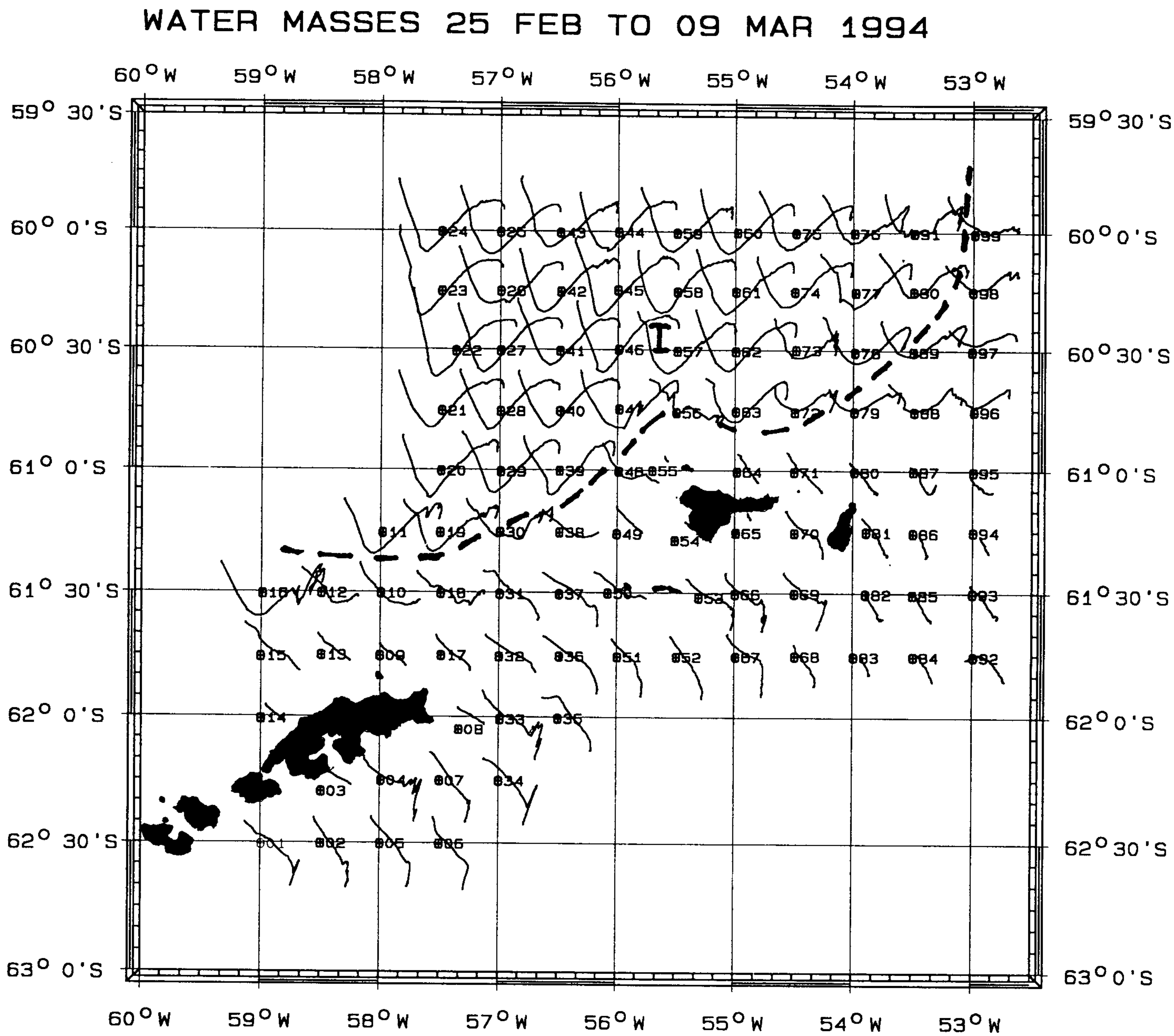


Figure 1.2a T/S curves for each station of Leg I's large-area survey (Survey A). The dotted line delineates the border of water type I from the other water types.



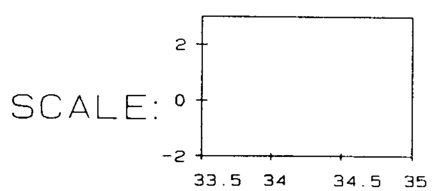


Figure 1.2b T/S curves for each station of Leg II's large-area survey (Survey D). The dotted line delineates the border of water type I from the other water types.

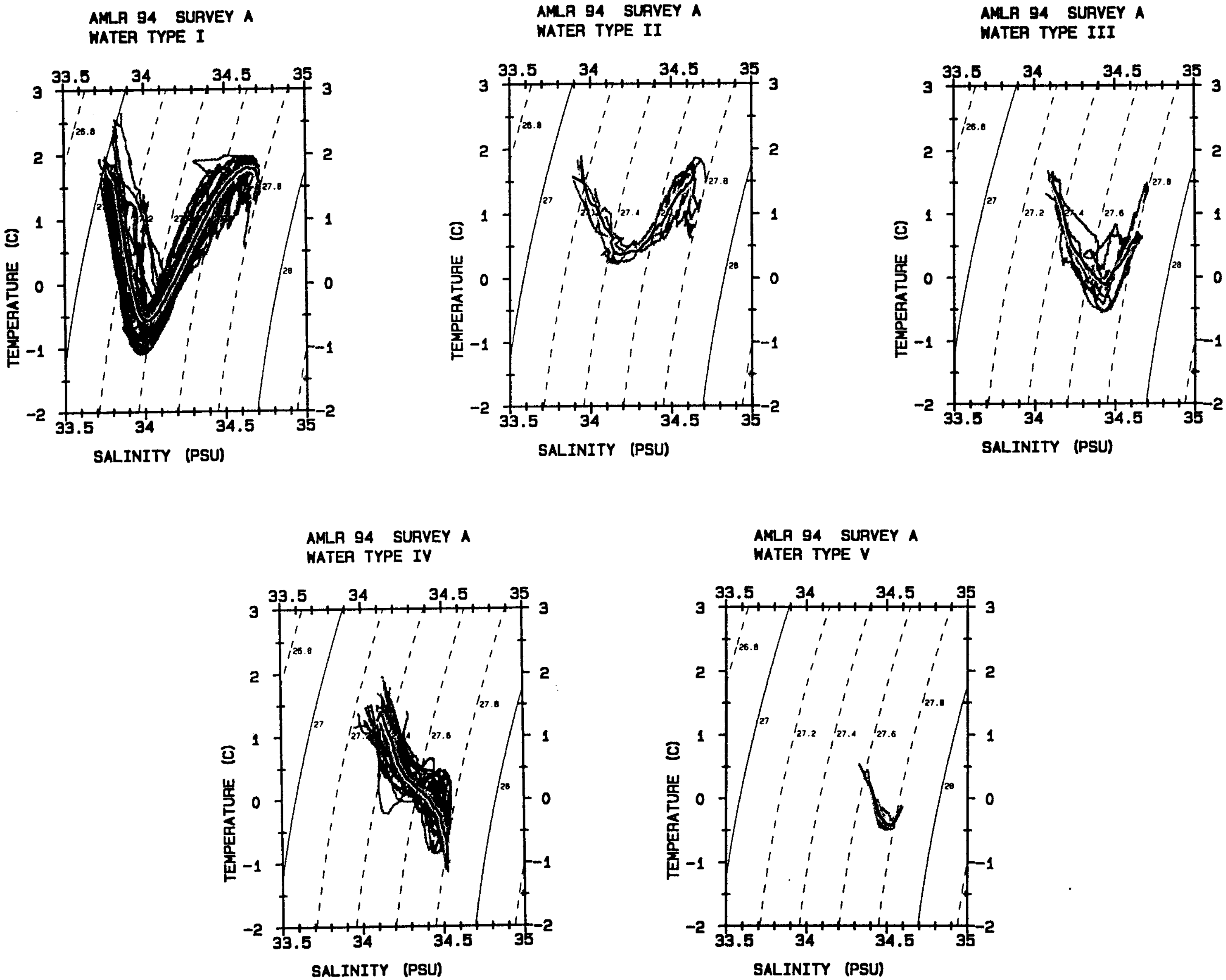
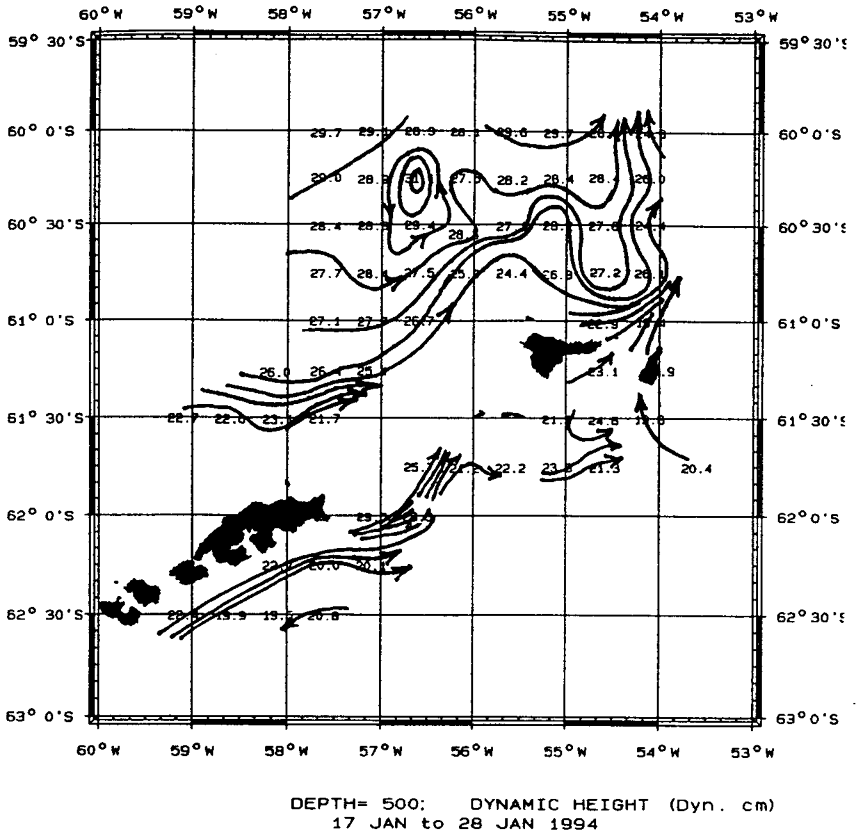
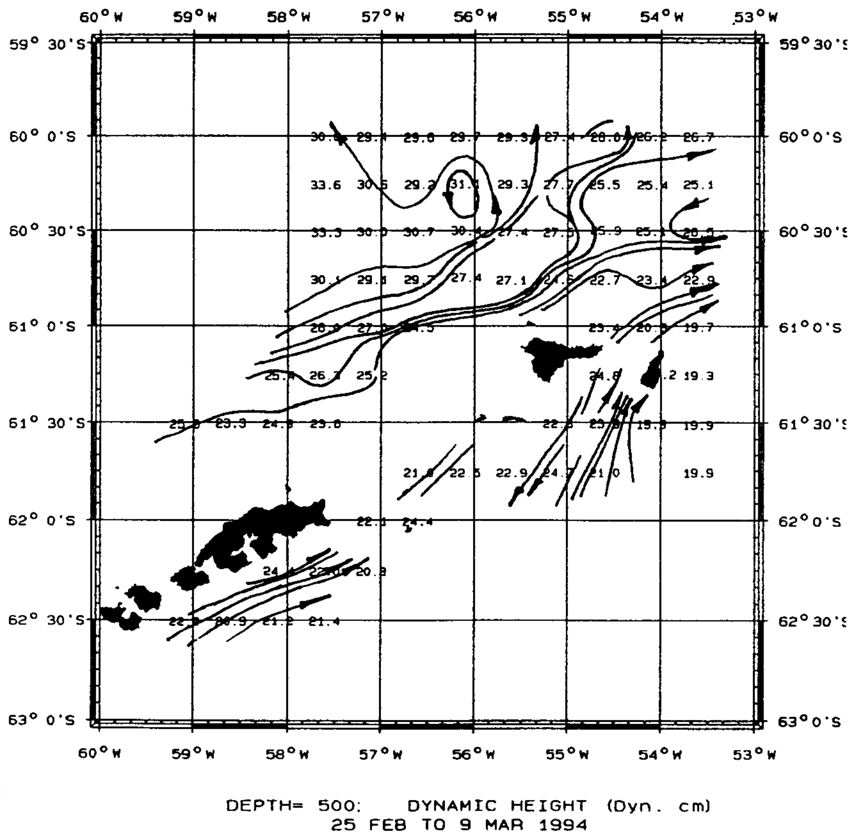


Figure 1.3 Five water types on separate panels. Dark curve represents the T/S characteristic of the specific water type.

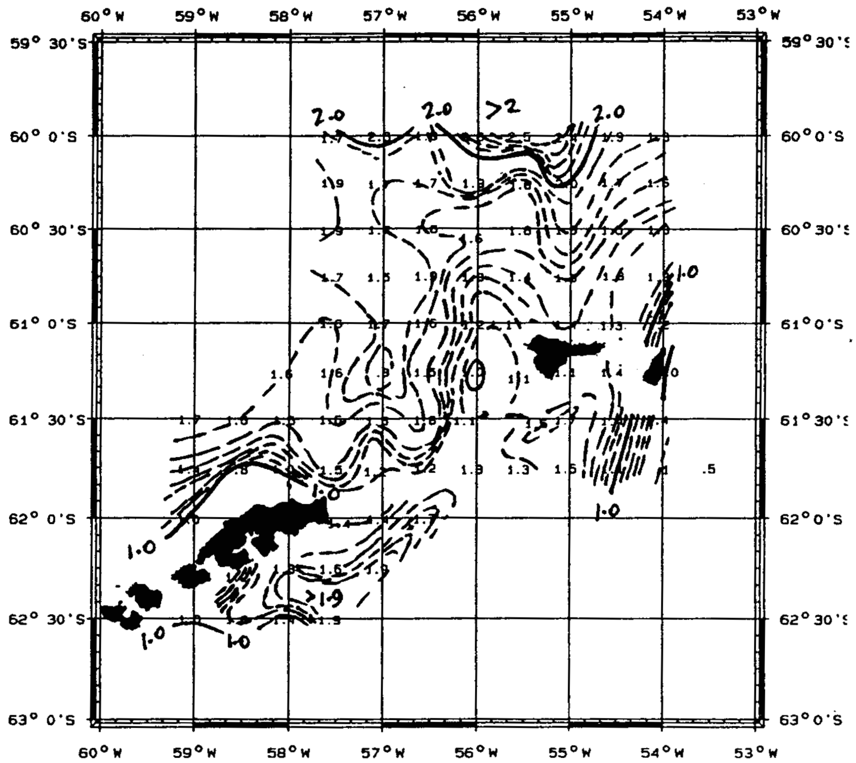


(a)



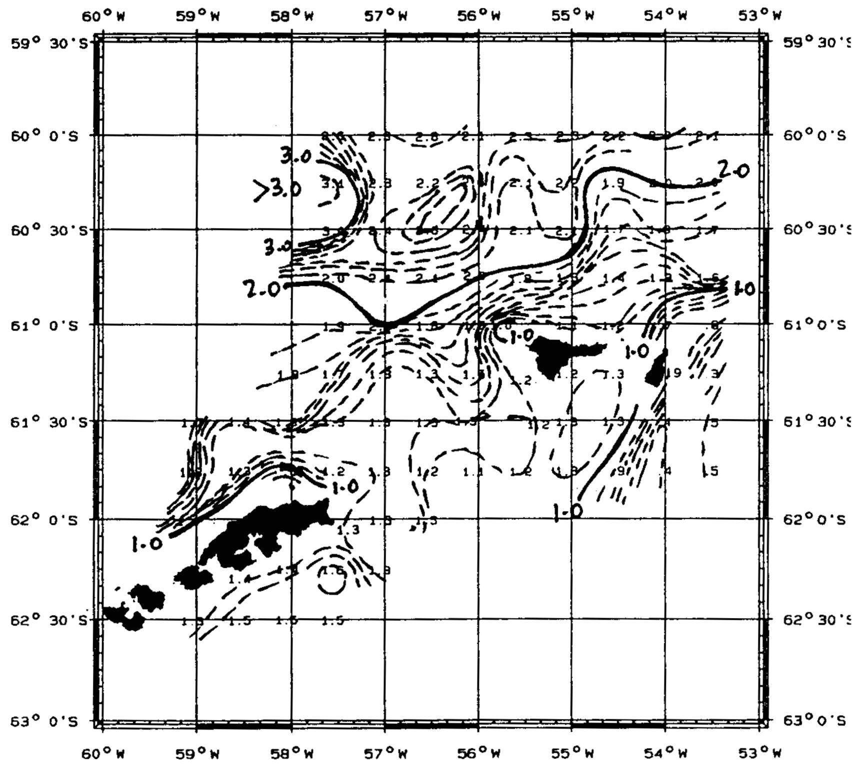
(b)

Figure 1.4 Dynamic topography. (a) Survey A and (b) Survey D.



(a)

DEPTH= 004: TEMPERATURE (C)
17 JAN to 28 JAN 1994



(b)

DEPTH= 004: TEMPERATURE (C)
25 FEB to 9 MAR 1994

Figure 1.5 Sea surface (4m depth) temperatures. (a) Survey A and (b) Survey D.

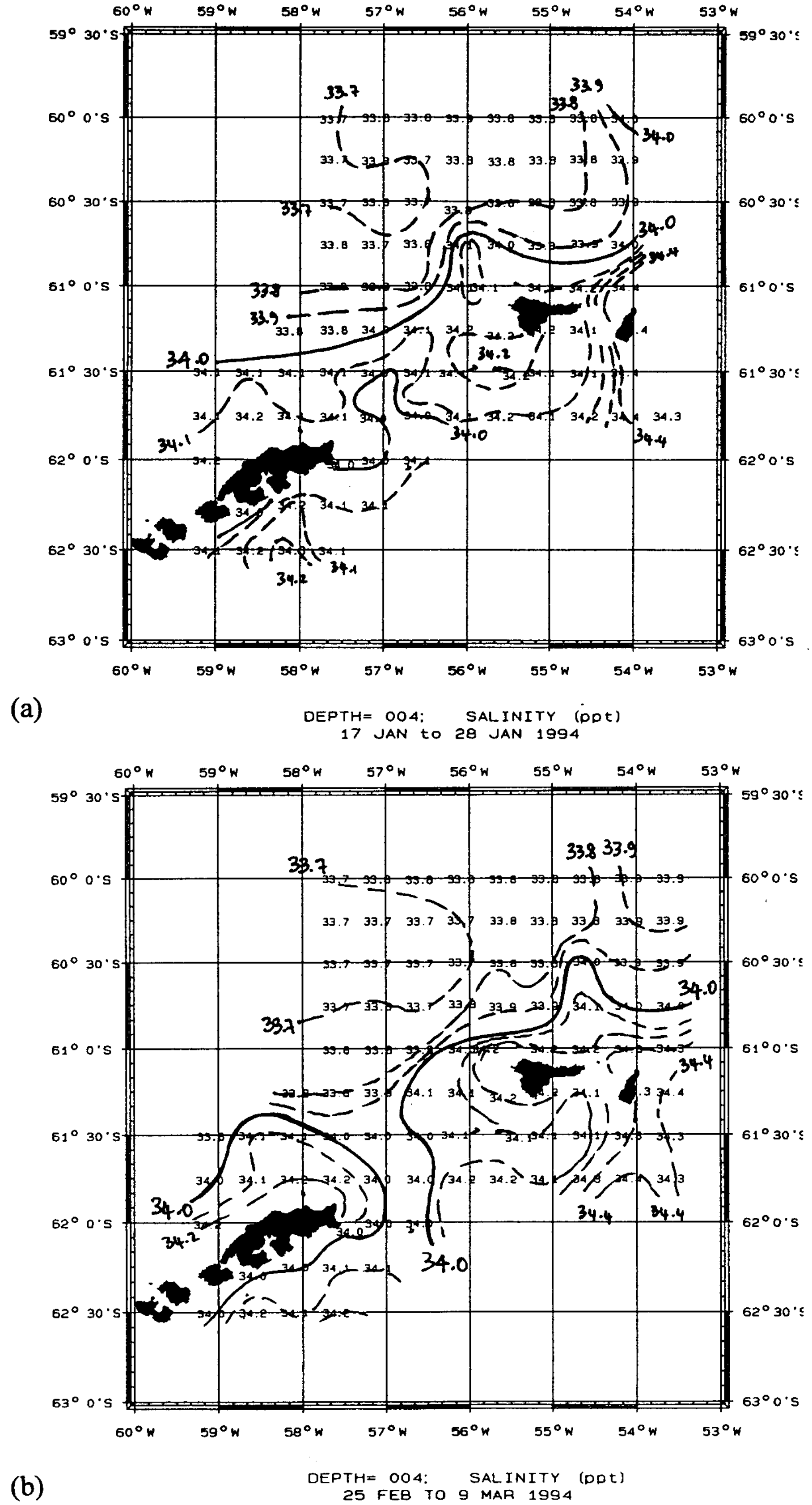


Figure 1.6 Sea surface (4m depth) salinities. (a) Survey A and (b) Survey D.

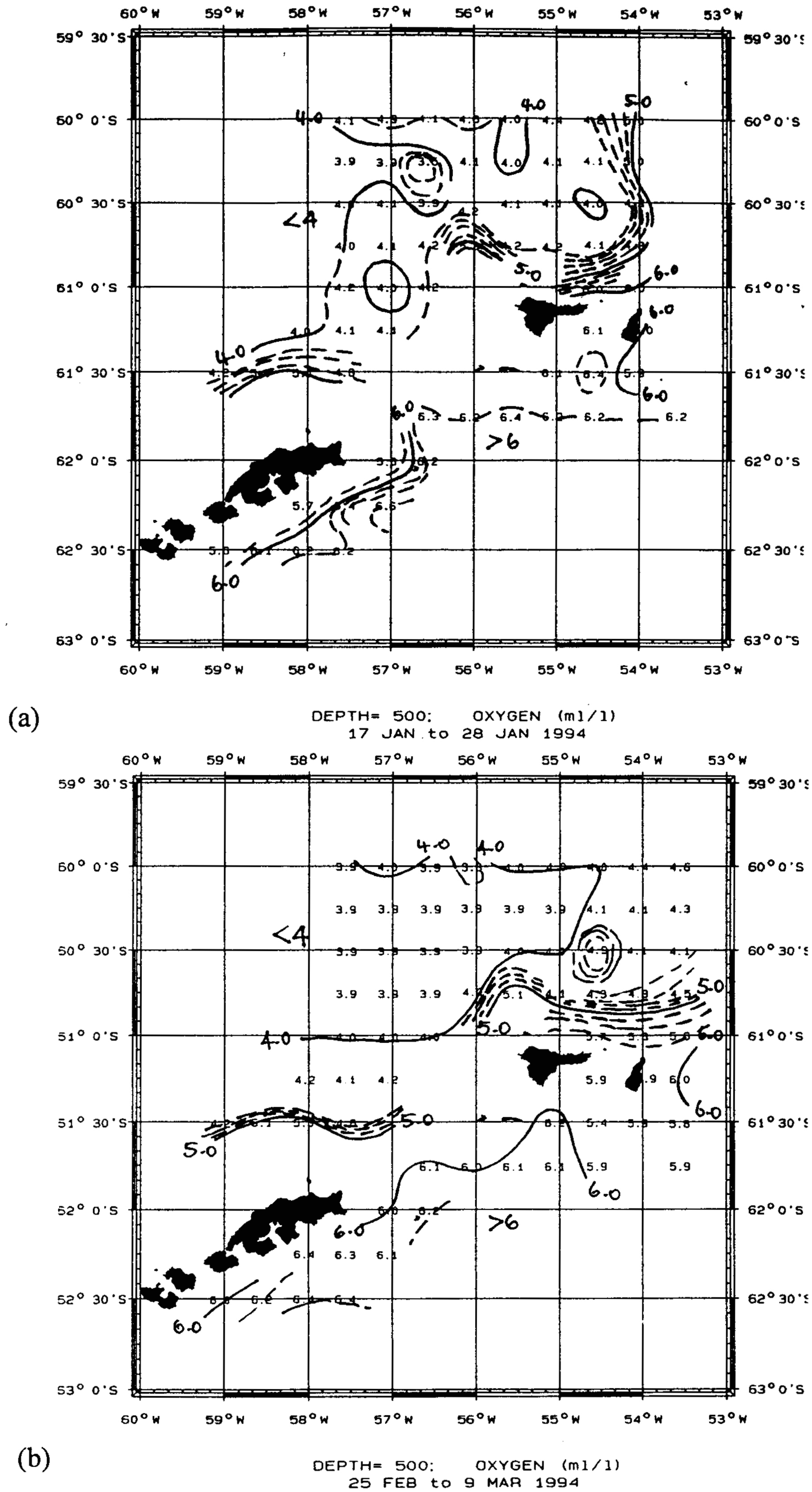


Figure 1.7 Horizontal distribution of dissolved oxygen at 500m. (a) Survey A and (b) Survey D.

2. Phytoplankton; submitted by Osmund Holm-Hansen (Leg II), E. Walter Helbling (Leg I), Virginia Villafañe (Leg I), Humberto Diaz (Legs I and II), Marcel Ramos (Legs I and II), Christian Bonert Anwandter (Leg II), and Pedro Baron (Leg II).

2.1 Objectives: The overall objective of our research was to assess the distribution and concentration of phytoplankton throughout the AMLR study area during the austral summer months (January to March) relative to the food requirements of the herbivorous zooplankton populations. Specific objectives of our work included: (1) documentation of the distribution and biomass of phytoplankton in the upper water column (0 to 750m), with emphasis on the upper 100m; (2) determination of the rate of primary production, as well as the photo-adaptational state of the phytoplankton; (3) determination of the species composition and size distribution of the phytoplankton; and (4) analysis of the importance of physical, chemical, and optical characteristics in the upper water column as controlling factors for the distribution and photosynthetic activity of phytoplankton.

2.2 Methods and Accomplishments: The major types of data acquired during our studies are listed below, together with a brief statement regarding the methodology employed.

(A) Sampling Strategy.

Our protocol relied on the following methods to obtain water samples or data from various sensors: (1) Water samples were obtained from 10-liter Niskin bottles (with teflon covered springs) at standard depths (5, 10, 15, 20, 30, 40, 50, 75, 100, 200, and 750m, or within 10m of the bottom at the shallow stations) from every CTD cast, which numbered 97 casts on Leg I and 121 casts on Leg II. (2) Ship intake water (clean PVC line) from approximately 4m in depth was used to continuously monitor phytoplankton concentrations during the entire cruise and also to obtain water samples. (3) A phytoplankton net was deployed at approximately half of the CTD stations to obtain a sample of the larger phytoplankton. (4) A variety of automatic sensors, either mounted on the ship, on the CTD, or on a separate hand-deployed profiling solar irradiance unit, were used to obtain data as described below.

(B) Measurements and Data Acquired.

(1) Photosynthetic pigments: Chlorophyll-a (chl-a) concentrations, which are used to estimate phytoplankton biomass in terms of cellular organic carbon, were measured in all water samples obtained from the CTD casts and from the ship's flow-through system at each CTD station. Chl-a concentrations were determined on samples filtered through glass fiber filters, extracted in absolute methanol, and the fluorescence measured in a fluorometer. In addition, *in situ* chl-a concentrations were estimated by *in vivo* chl-a fluorescence measurements of the ship's clean seawater intake throughout the entire cruise and also with a pulsed fluorometer attached to the rosette.

(2) Biomass and organic carbon concentrations: The following samples and measurements were made to determine biomass in terms of carbon content: (a) Samples were filtered for

determination of particulate organic carbon (POC) and nitrogen (PON), which will be done later by gas chromatographic techniques. (b) Data on beam attenuation coefficients obtained from the two transmissometers (one on the rosette and one on the ship's flow-through system) will be used to estimate POC by use of an algorithm we have developed from our past data sets. (c) Over 200 water samples were preserved with buffered formalin for later determination of phytoplankton cell numbers, sizes and shapes, from which total cellular volumes and organic carbon can be estimated.

(3) Phytoplankton cell size and species composition: At every CTD station, the following samples were obtained: (a) samples for chl-a determination were filtered-fractionated (Nitex nylon mesh, 20μm pore size) to determine the contribution of the nanoplankton- and microplankton-sized phytoplankton to the total chl-a of the community; and (b) samples for floristic analyses. At every other station, a plankton net (20μm) was deployed (horizontal tow, 5 minutes) to determine net plankton abundance and composition.

(4) Rate of primary production: At 25 stations (13 in Leg I and 12 in Leg II), water samples were obtained from eight depths (5 to 75m) at an early-morning CTD cast, inoculated with radiocarbon labelled bicarbonate, and exposed to solar radiation for the rest of the day in a flowing seawater incubator mounted on the helopad. Neutral density screening was used to simulate the irradiance to which the phytoplankton would have been exposed at the depths that they were sampled. Irradiance incident upon the samples varied from 95% to 0.5% of direct solar radiation. Data from these experiments will be used to calculate the rate of primary production occurring in the AMLR study area. Simultaneous with these primary production experiments, replicate water samples from 5m and from one depth between 40-100m were also inoculated with radiocarbon and incubated under irradiances varying from 95% to 0.5% of incident solar radiation. These data will be informative regarding the photo-adaptational state of the phytoplankton, which in turn is largely dependent upon the rate of mixing in the upper water column.

We also deployed our PUV-500 profiling unit to 80m depth at 22 CTD stations and measured the upwelling light at 683nm throughout the upper water column as a function of depth and *in situ* irradiance. This technique to measure instantaneous rates of primary production in the water column is still in the exploratory state; if it is reliable, it would offer a rapid method of estimating primary production without the problems involved with the conventional radiocarbon incubation technique.

(5) Nutrients: Water samples for measurement of nitrite, nitrate, phosphate, and silicate were taken at all survey stations at two depths (5 and 200m). In addition, nutrients were collected at seven depths (5, 20, 50, 100, 200, 400m, and bottom) at all of the cross-shelf transect stations, and also for the large-area survey stations in two north-south lines (station numbers 25 to 34 and 76 to 83). All nutrient samples were frozen (-20°C) for later analysis at Universidad Católica de Valparaiso (Chile).

(6) Solar radiation measurements: The following data on incident solar radiation were

collected throughout the entire cruise: (a) continuous monitoring (every minute) of Photosynthetic Available Radiation (PAR) using a 2-pi collector (instrument located on the flying bridge); (b) continuous monitoring (every minute) of PAR and four different channels (308, 320, 340 and 380nm) of UV radiation (instrument on the helopad adjacent to the incubators); (c) vertical depth recording of underwater PAR (sensor mounted on the rosette) for measurement of the attenuation of solar radiation in the water column; and (d) hand deployment of a profiling unit to measure PAR, four channels of UVR, temperature, and 683nm upwelling light (0 to near 100m) when weather conditions permitted.

2.3 Results and Tentative Conclusions:

(A) Phytoplankton distribution at 5m depth throughout the large-area survey grid, as indicated by chl-a concentrations (mg m^{-3}), is shown for Legs I and II in Figures 2.1 and 2.2, respectively. Three major observations based on these data are: (1) Chl-a concentrations in surface waters were low in Drake Passage and Weddell Sea water masses (water types I and V in Physical oceanography report by Amos et al.) and much higher in water types II (Transition), III (Weddell-Scotia Confluence), and IV (Bransfield Strait). (2) The highest phytoplankton biomass was found in Bransfield Strait water. (3) The phytoplankton biomass in water types I and V were approximately the same in both legs, but the biomass in Bransfield Strait waters (type IV) during Leg II was approximately four times higher than during Leg I.

(B) The integrated chl-a concentrations (mg chl-a m^{-2}, 0 to 100m depth) are shown in Figures 2.3 and 2.4 for Legs I and II, respectively. The patterns of integrated chl-a concentrations are fairly similar to the patterns for surface chl-a concentrations. The integrated chl-a values for stations in Bransfield Strait during Leg II were very high (100 to 250mg m^{-2}) when compared to most Antarctic waters.

(C) Vertical sections showing chl-a concentrations in two north-south transects within the large-area survey grid (Stations D25-D34 and D76-D83) are shown in Figures 2.5 and 2.6, respectively. The distribution of chl-a in these sections is supportive of the observations stated above.

(D) During Survey B, the phytoplankton biomass and distribution were estimated from the data obtained at 4m depth with instruments installed in the flow-through system. Particulate beam attenuation coefficients (obtained from the transmissometer data) were contoured and are shown in Figure 2.7. Highest beam attenuation values (indicating high concentrations of phytoplankton) were found in the area to the northwest of Elephant Island.

(E) Preliminary analysis of chl-a concentration data suggests at least two distinct patterns of phytoplankton distribution with depth: (1) The first group of stations, usually located in pelagic Drake Passage waters, showed a sub-surface chl-a maximum at a depth varying from 50 to 100m. These sub-surface chl-a maxima were in general associated with the temperature minimum. (2) The second group of stations, located in water types II, III, and IV, showed high and fairly uniform values of chl-a within the upper mixed layer (UML), with the chl-a concentrations decreasing rapidly with depth below the UML.

Typical profiles of the upper 200m of the water column for stations in pelagic Drake Passage waters are shown in Figure 2.8 for Station A27. There is a shallow mixed layer at 40m (Figure 2.8A). Phytoplankton biomass is relatively low in the UML, with increased concentrations between 40 to 120m, as evidenced by the data presented in Figure 2.8B (note changes in slope at approximately 40 and 100m), Figure 2.8C (transmissometer data that indicate high concentrations of particles below the mixed layer and reach a maximum at about 80m), and Figure 2.8D (*in vivo* fluorescence of chl-a and extracted chl-a concentrations). Data in Figure 2.9 show profiles for Station A70, which is representative for most stations in water types II, III, and IV. There was a low density layer at this station at about 65m, but it was not well mixed. Highest concentrations of phytoplankton were found in the upper 40m, with concentrations decreasing below that depth.

(F) The attenuation of solar visible radiation and four channels of ultraviolet radiation are shown in Figures 2.10, 2.11, and 2.12 for stations with low, medium, and high phytoplankton biomass, respectively. These figures also show the temperature profile and the rate of photosynthesis with depth as determined by measurement of upwelling irradiance at 683nm. The euphotic zone depth extends to approximately 85, 56, and 20m in depth at these three stations. Penetration of UV-B radiation (280-320nm) was observed down to 20m depth and UV-A radiation (320-400nm) down to more than 50m.

(G) The distribution of chl-a in the upper 100m for the transect across Bransfield Strait (Stations X08-X21) is shown in Figure 2.13, while that for the north-south transect to the east of the large-area survey grid (Stations X30-X37) is shown in Figure 2.14. Station X08, which is located in Weddell Sea water type, had low phytoplankton biomass, while stations in the mid-section of the Strait had very high chl-a concentrations. High chl-a concentrations were also found at some of the stations north of King George Island, but the outermost stations (X20-X21), which were located in water type I, had low phytoplankton biomass characteristic of Drake Passage waters. The chl-a concentrations of the stations shown in Figure 2.14 were unexpectedly high, as nearby stations (for example, 83 and 84) normally have very low phytoplankton biomass.

2.4 Disposition of the Samples and Data: The nutrient samples will be processed at the Universidad Católica de Valparaiso (Chile). All other samples (for radiocarbon measurements, CHN analysis, floristic determinations) were returned to SIO for processing. All data obtained during the cruise have been stored on duplicate 90 Mbyte Bernoulli disks. After checking the data at SIO, a copy of all data will be deposited at the AERG office in La Jolla, CA. Copies of any of our data sets are available to all other AMLR investigators upon request.

2.5 Problems and Suggestions: It is strongly suggested that the entire rosette system be checked for correct functioning before the start of any routine work, particularly the closing of the Niskin bottles. This could be accomplished by conducting a practice depth profile at the same time that the acoustic calibration is done.

At times fumes and particulate material emanating from the boat deck incinerator caused problems, both in regards to possible deleterious effects on human health and also the contamination of our various samples. It would be appreciated if this matter was examined by the appropriate medical and environmental specialists.

It is also suggested that we consider including in next year's work: (a) another full transect across the Bransfield Strait and extending into the Bellingshausen Sea; (b) a transect from the end of the Antarctic Peninsula to north of the Scotia ridge and to the east of Clarence Island; and (c) a few zig-zag transects across the Scotia arc from the AMLR survey grid to the South Orkney Islands.

2.6 Acknowledgments: We want to express our sincere thanks to all officers and crew of the NOAA Ship *Surveyor* for their generous help in all matters relating to work and life on board the ship. Particular appreciation must be extended to the personnel involved in the deployment of the CTD profiling system; they completed over 200 successful deployments of the rosette system without any mishaps, in spite of some adverse sea conditions. We also thank all other AMLR personnel for help, support, and data which enhanced the productivity of the phytoplankton program. Special thanks are extended to the Physical oceanography group, who interfaced many of our instruments with their data acquisition system. We also thank Drs. Rennie Holt and Roger Hewitt who served so well as Chief Scientists during the cruise.

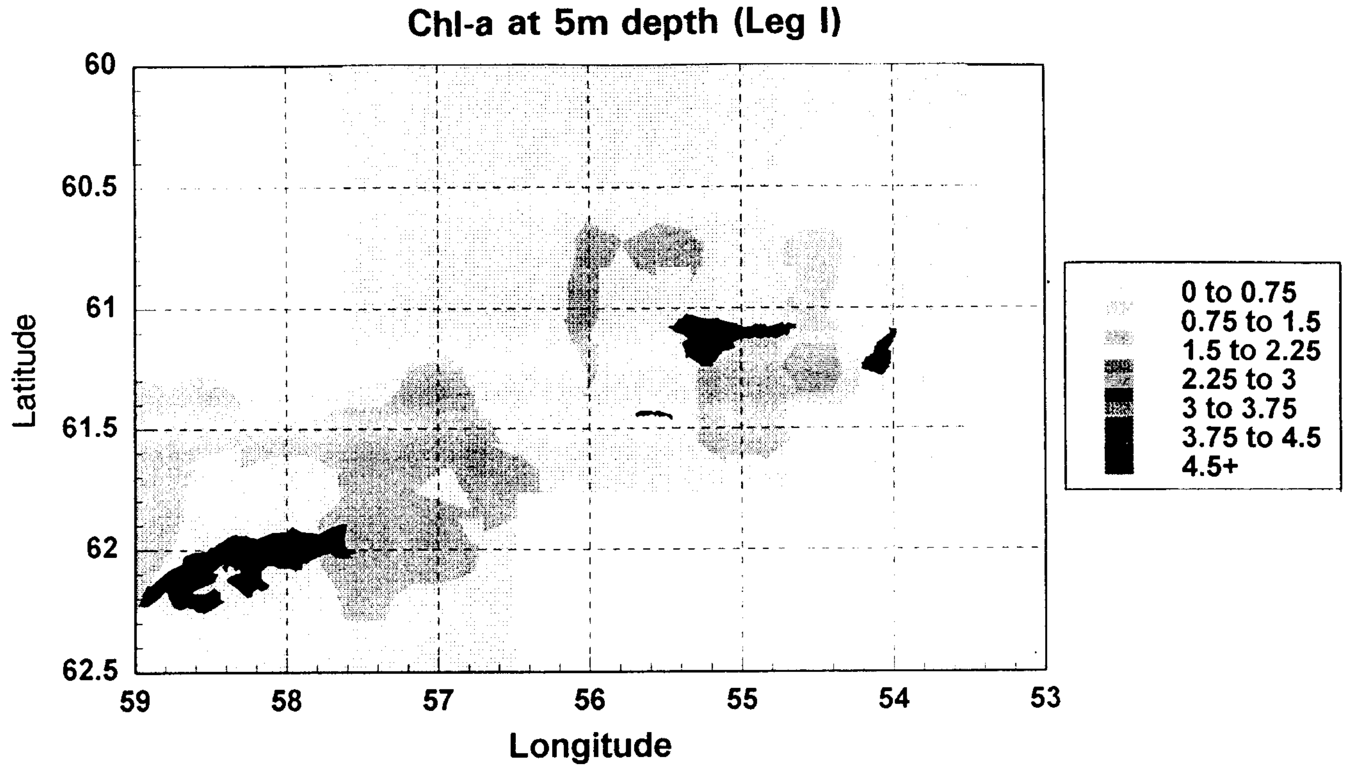


Figure 2.1 Distribution of chl-a at 5m depth (mg m^{-3}) throughout large-area survey grid (Survey A).

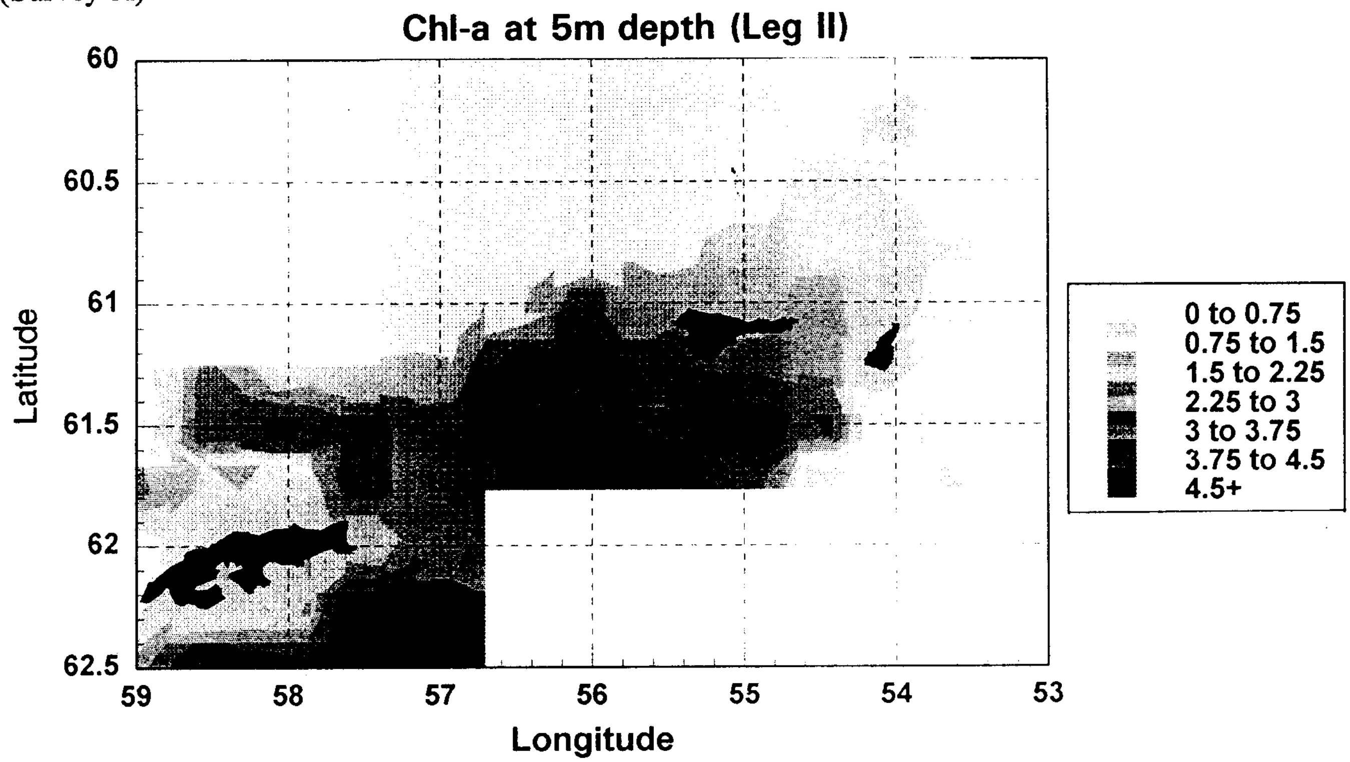


Figure 2.2 Distribution of chl-a at 5m depth (mg m^{-3}) throughout large-area survey grid (Survey D).

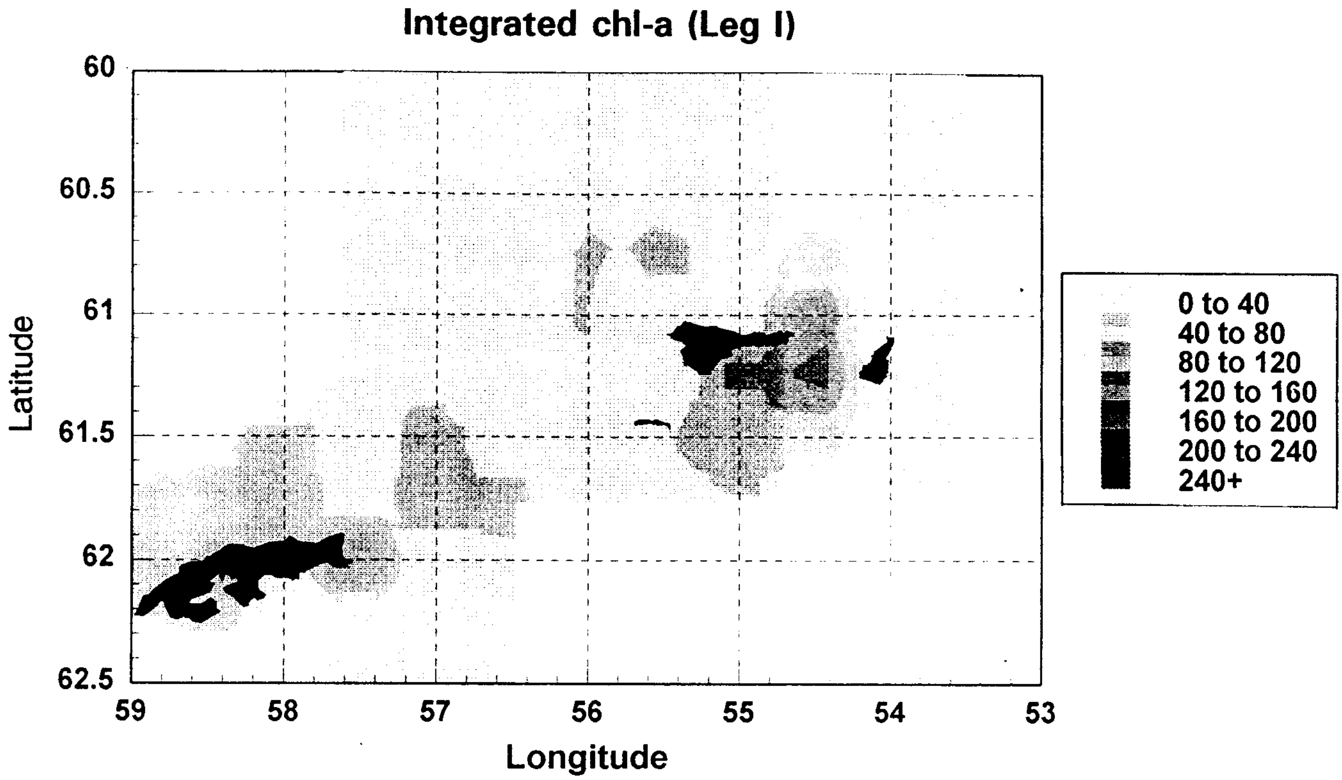


Figure 2.3 Distribution of integrated chl-a (mg m^{-2}, 0 to 100m) throughout large-area survey grid (Survey A).

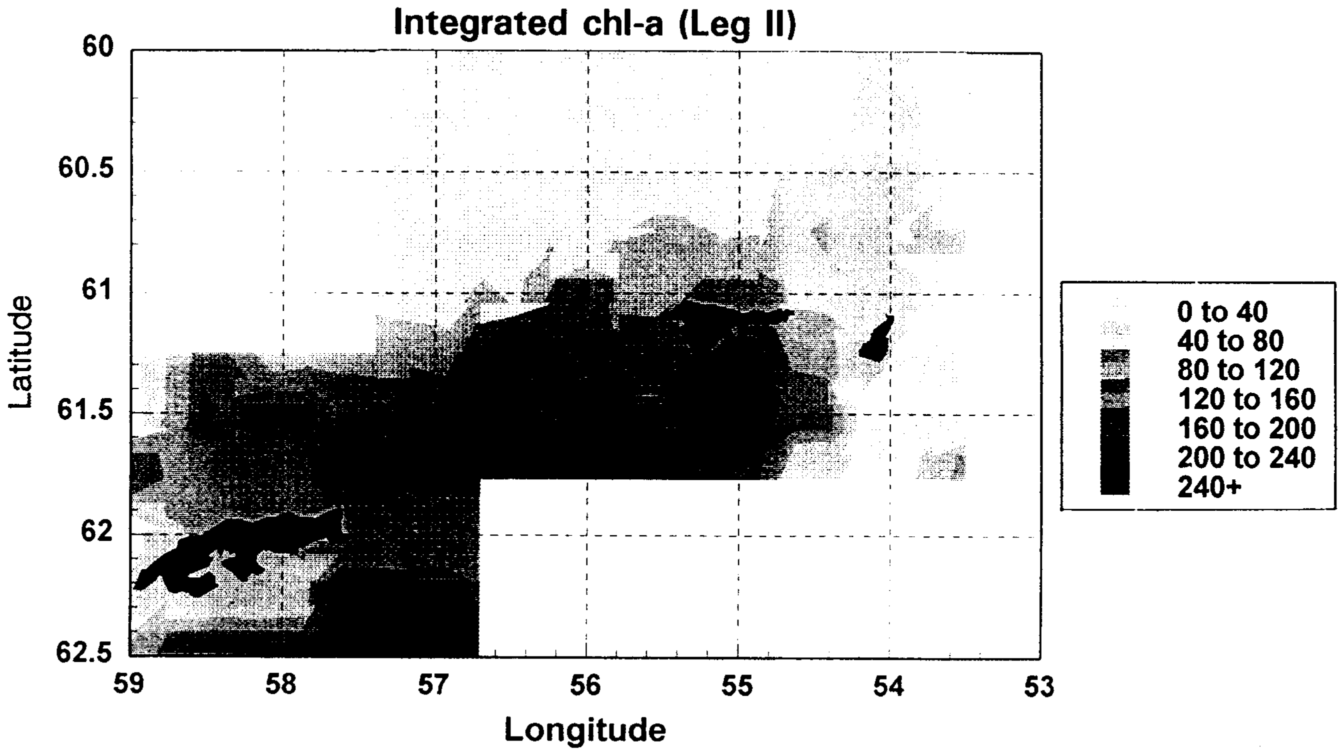


Figure 2.4 Distribution of integrated chl-a (mg m^{-2}, 0 to 100m) throughout large-area survey grid (Survey D).

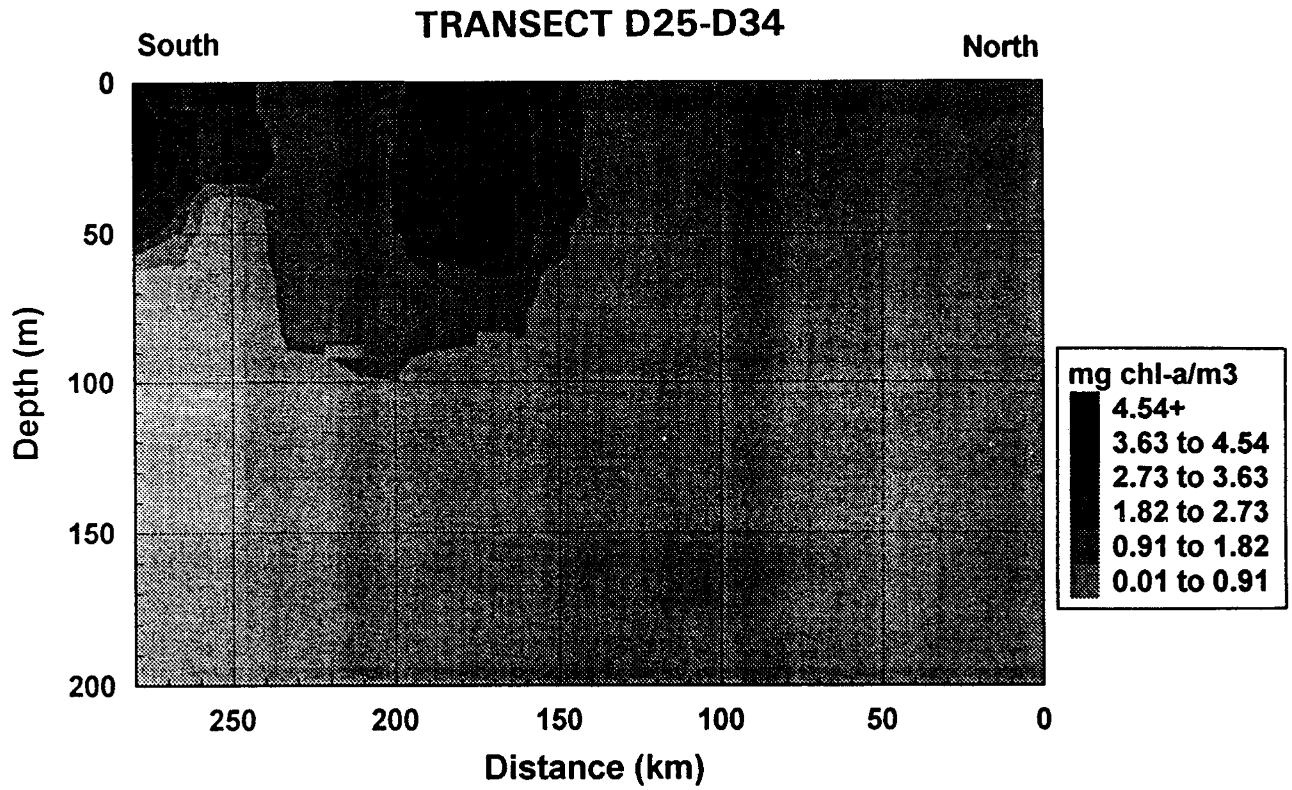


Figure 2.5 Distribution of chl-a (mg m^{-3}) in the upper 200m of the water column in a north-south transect of Survey D (Stations D25-D34).

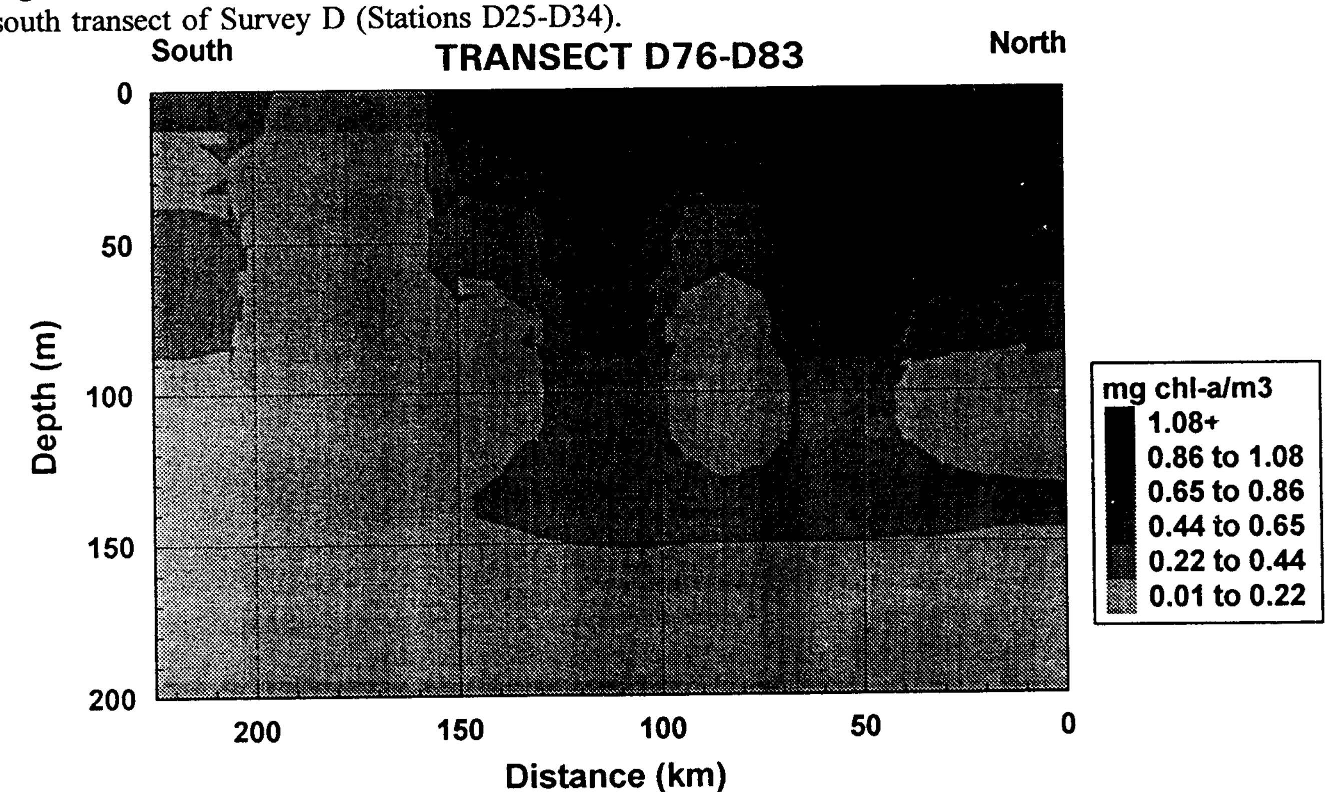


Figure 2.6 Distribution of chl-a (mg m^{-3}) in the upper 200m of the water column in a north-south transect of Survey D (Stations D76-D83).

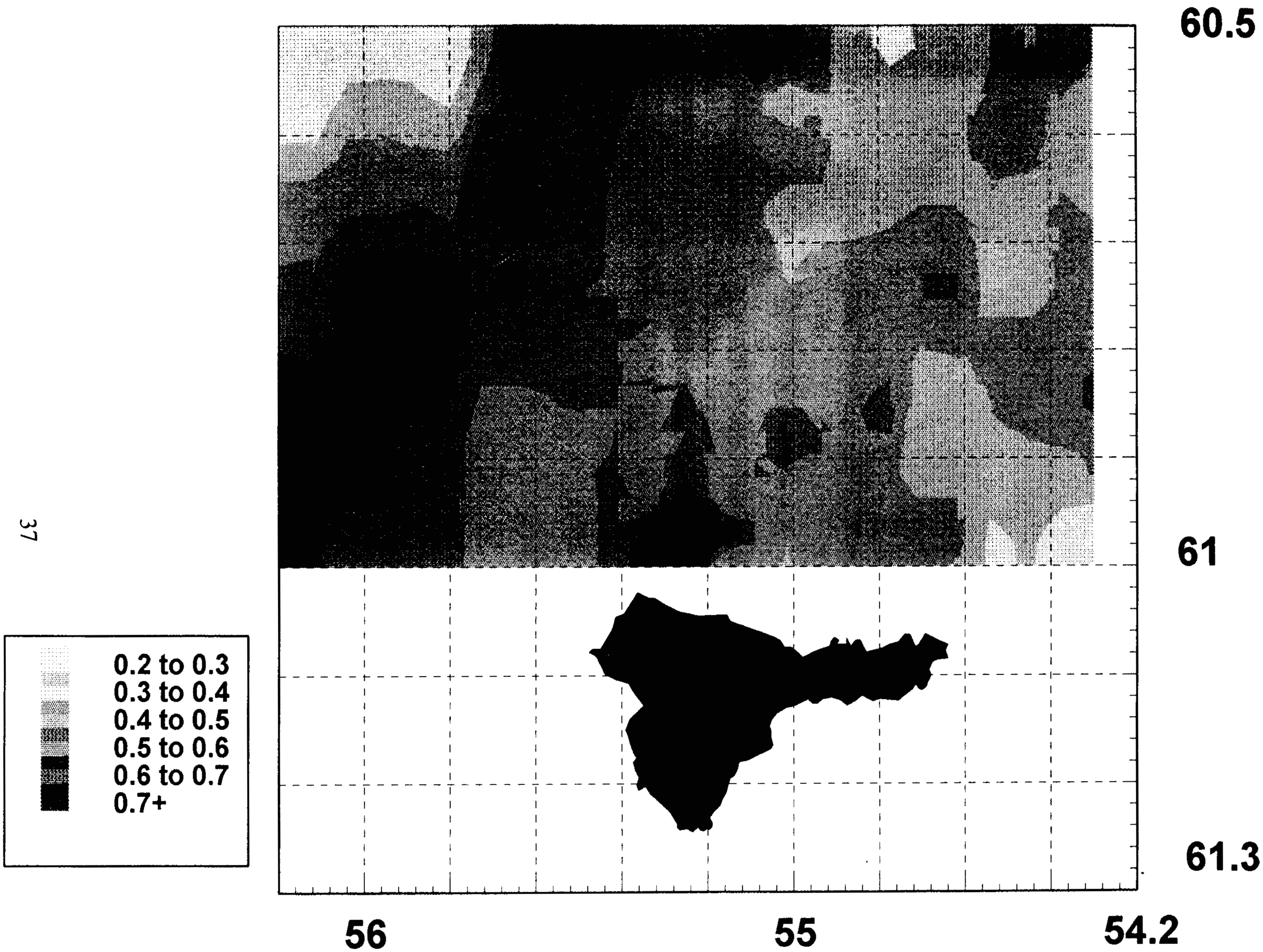


Figure 2.7 Beam attenuation coefficients (m^{-1}) for surface waters during Survey B.

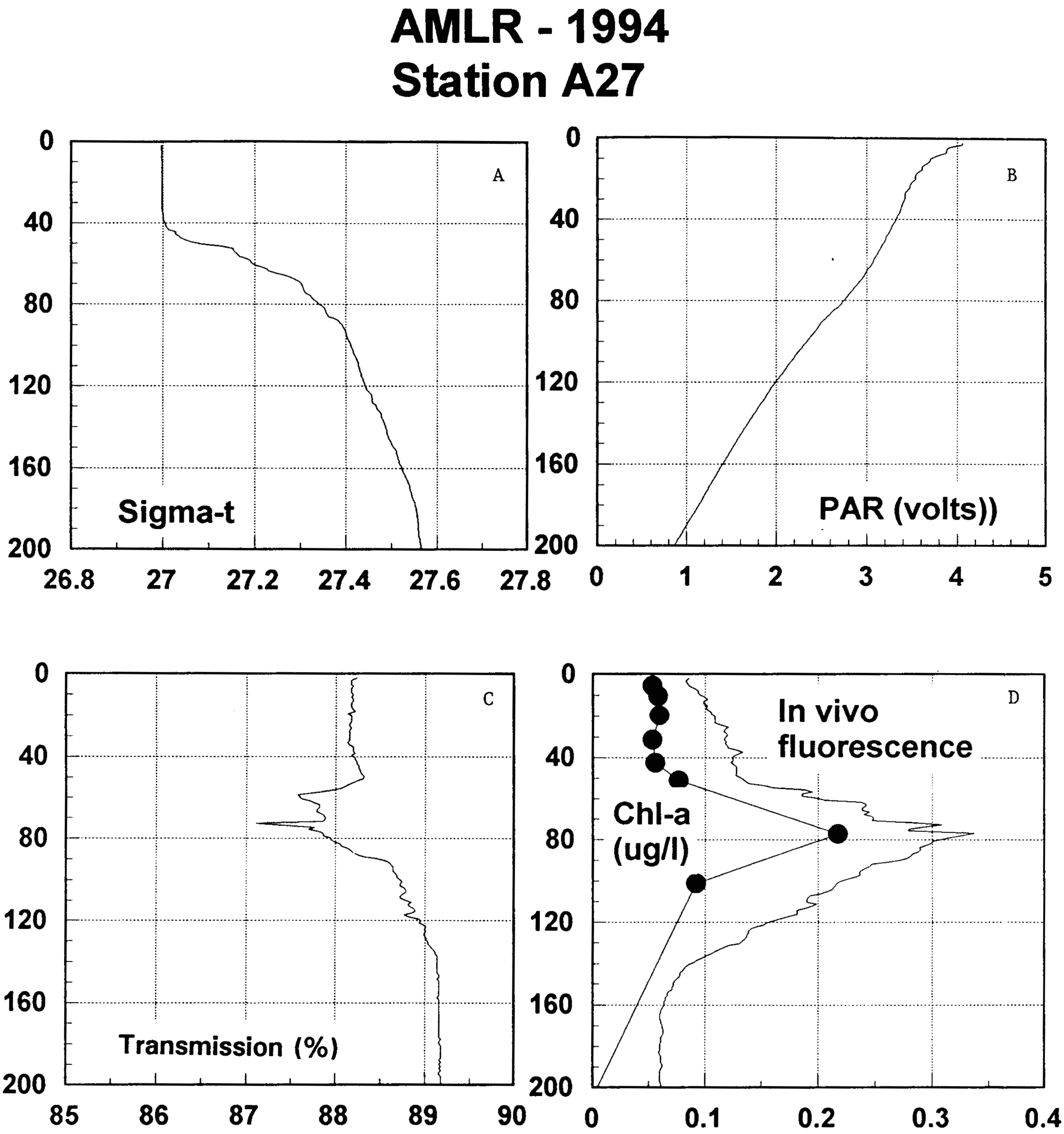


Figure 2.8 Upper water column characteristics (0 to 200m) at Station A27 in Drake Passage waters. (A) Profile of water density. (B) Attenuation of solar irradiance with depth. (C) Percent transmission of light as determined with a transmissometer. (D) Profile of *in vivo* chl-a fluorescence (continuous line) and extracted chl-a concentrations (values shown on abscissa).

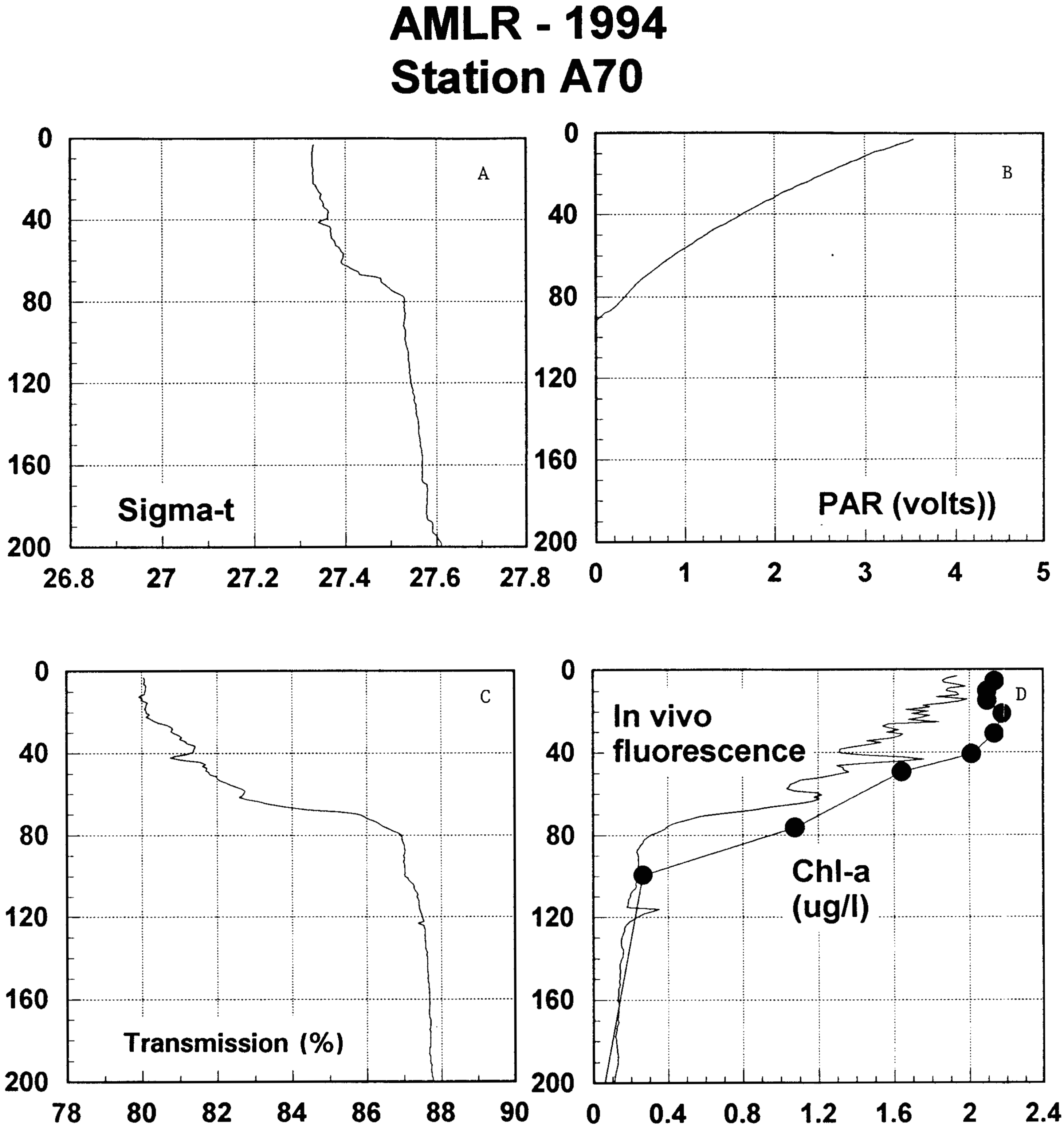
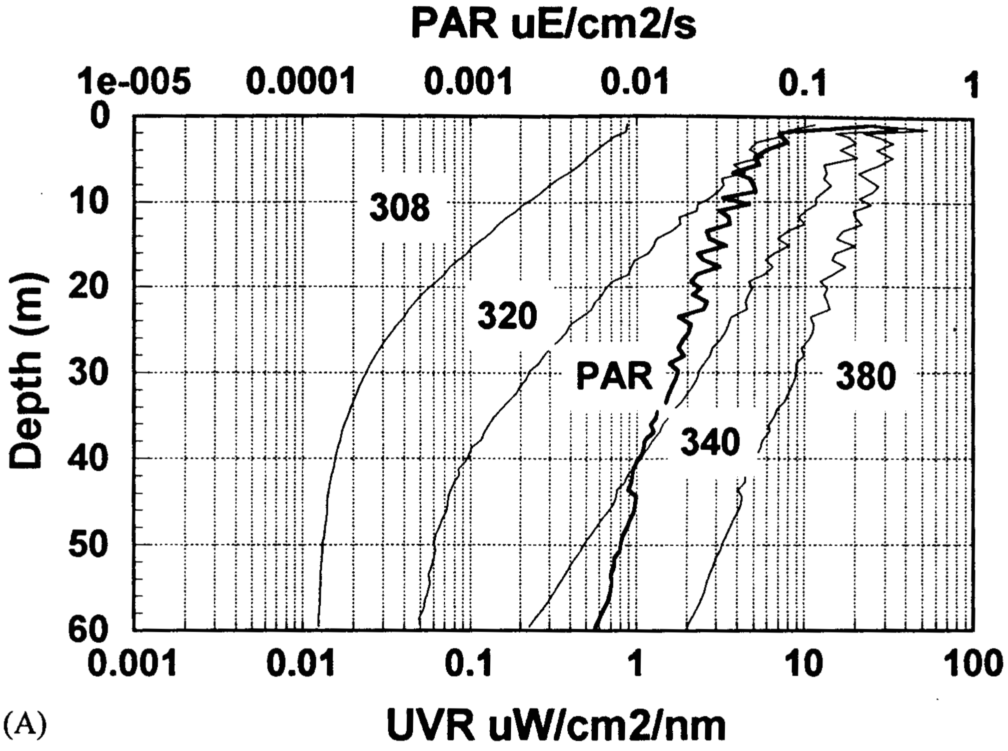
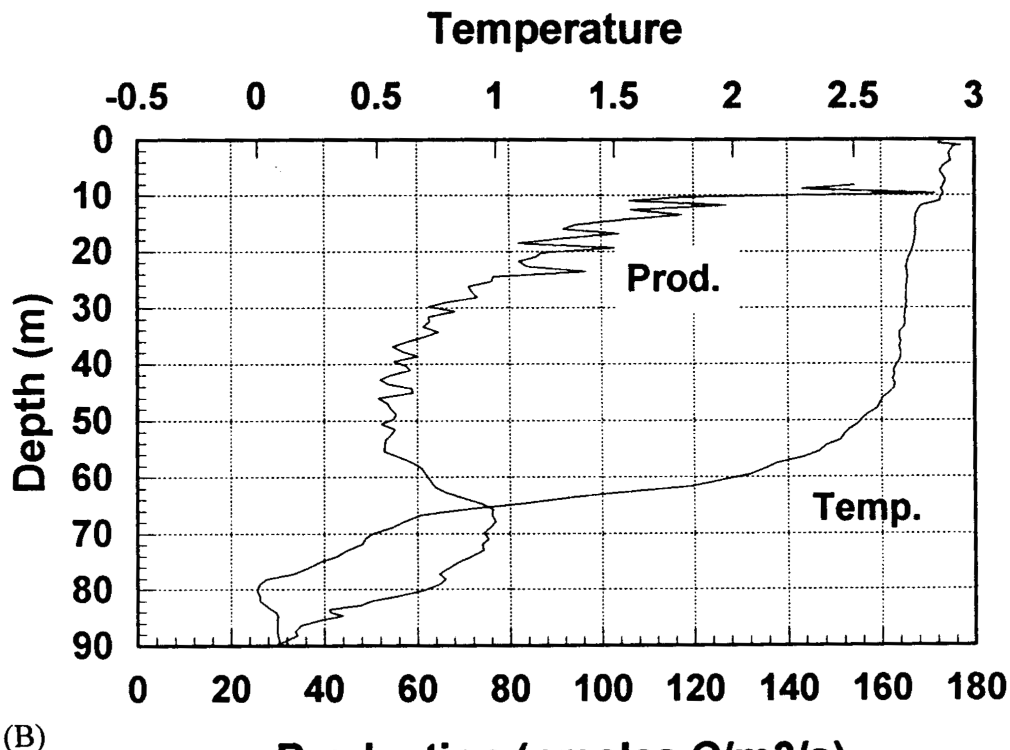


Figure 2.9 Upper water column characteristics (0 to 200m) at Station A70 in Bransfield Strait waters. (A) Profile of water density. (B) Attenuation of solar irradiance with depth. (C) Percent transmission of light as determined with a transmissometer. (D) Profile of *in vivo* chl-a fluorescence (continuous line) and extracted chl-a concentrations (values shown on abscissa).



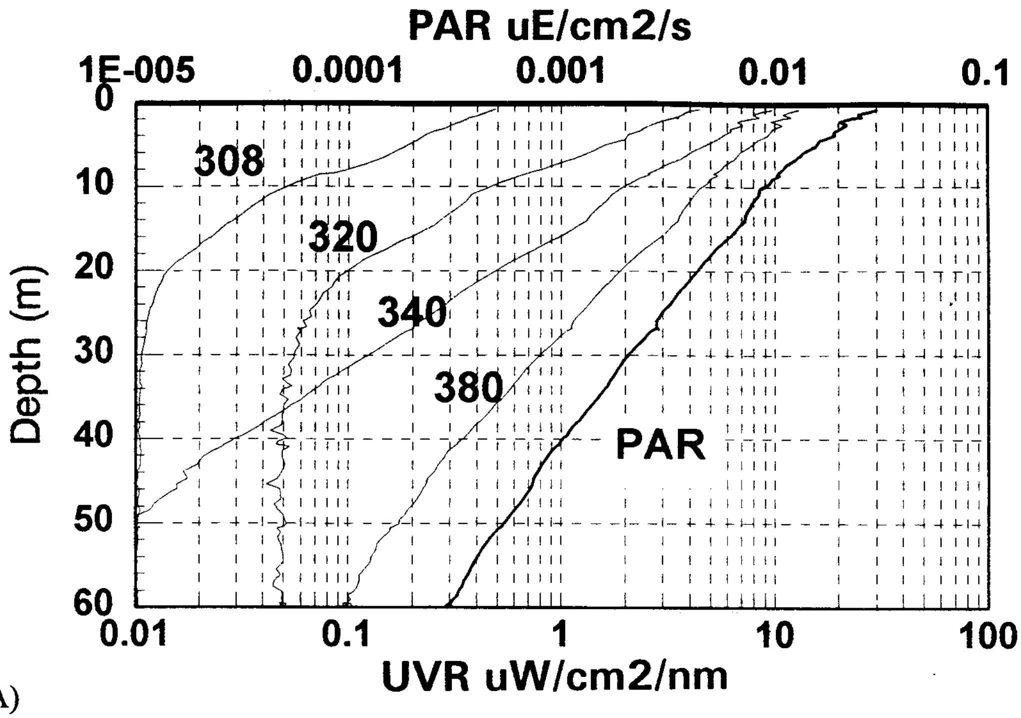
(A)



(B)

Figure 2.10 Optical characteristics of the upper water column at a low chl-a station (Station D41; mean chl-a concentration about 0.06 mg m^{-3}). (A) Attenuation of four ultraviolet wavelengths (lower abscissa) and of PAR (upper abscissa) with depth. The vertical portions of the lines for 308 and 320nm represent "dark noise" of the sensor and are below the detection threshold at those depths. (B) Profiles for instantaneous rate of photosynthesis as estimated by upwelling irradiance at 683nm and for water temperature.

(A)



(B)

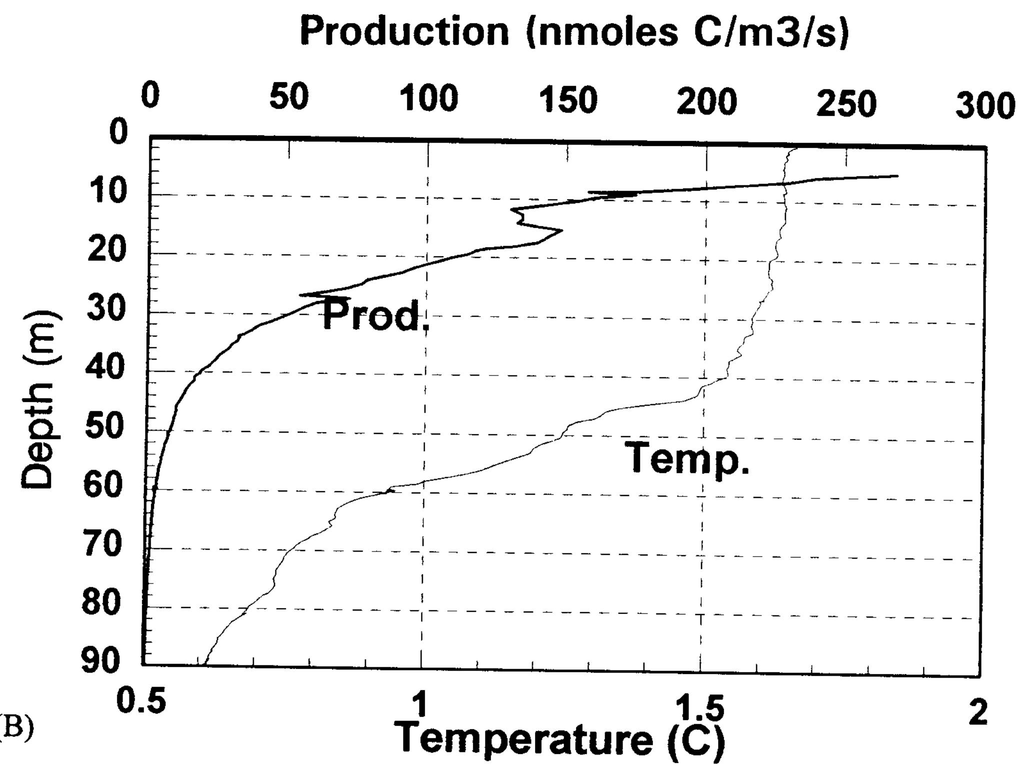
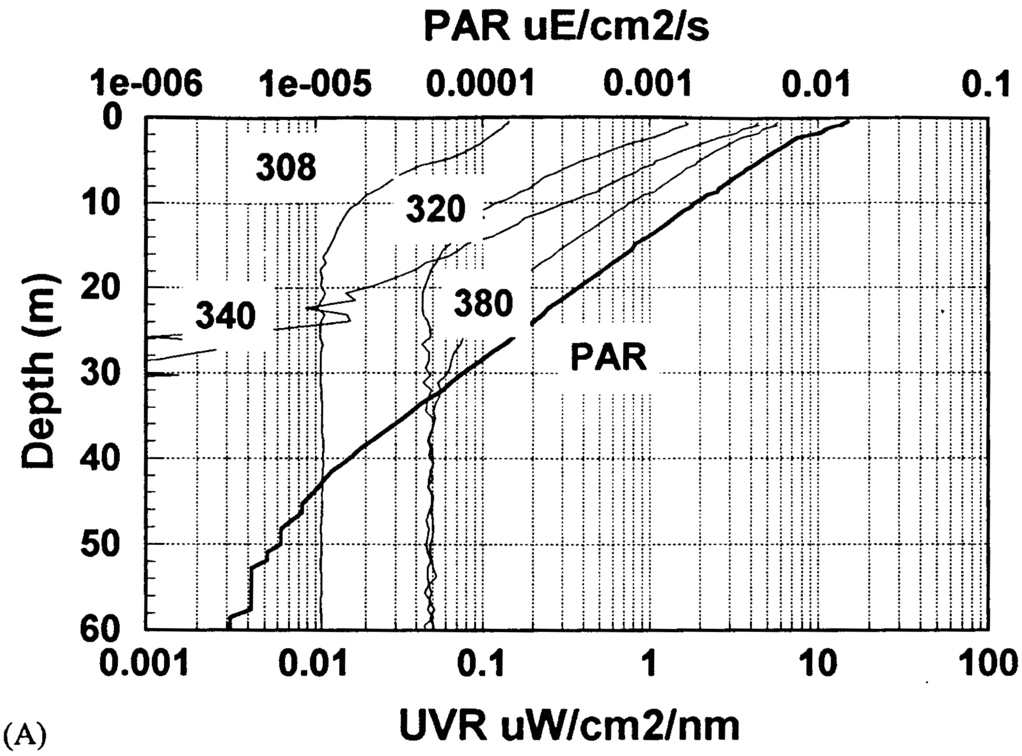
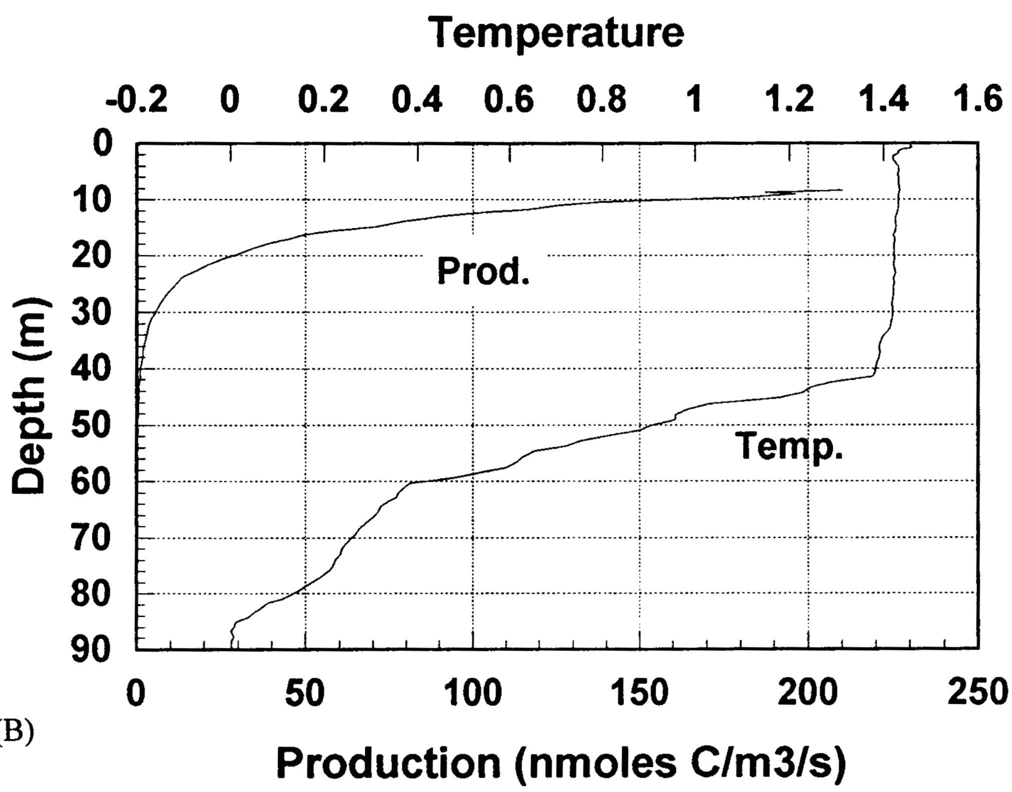


Figure 2.11 Optical characteristics of the upper water column at a medium chl-a station (Station A17; mean chl-a concentration about 0.7 mg m^{-3}). (A) Attenuation of four ultraviolet wavelengths (lower abscissa) and of PAR (upper abscissa) with depth. The vertical portions of the lines for 308 and 320nm represent "dark noise" of the sensor and are below the detection threshold at those depths. (B) Profiles for instantaneous rate of photosynthesis as estimated by upwelling irradiance at 683nm and for water temperature.



(A)



(B)

Figure 2.12 Optical characteristics of the upper water column at a high chl-a station (Station D34; mean chl-a concentration about 4.5 mg m^{-3}). (A) Attenuation of four ultraviolet wavelengths (lower abscissa) and of PAR (upper abscissa) with depth. The irregular portions of the lines represent "dark noise" of the sensor and are below the detection threshold at those depths. (B) Profiles for instantaneous rate of photosynthesis as estimated by upwelling irradiance at 683nm and for water temperature.

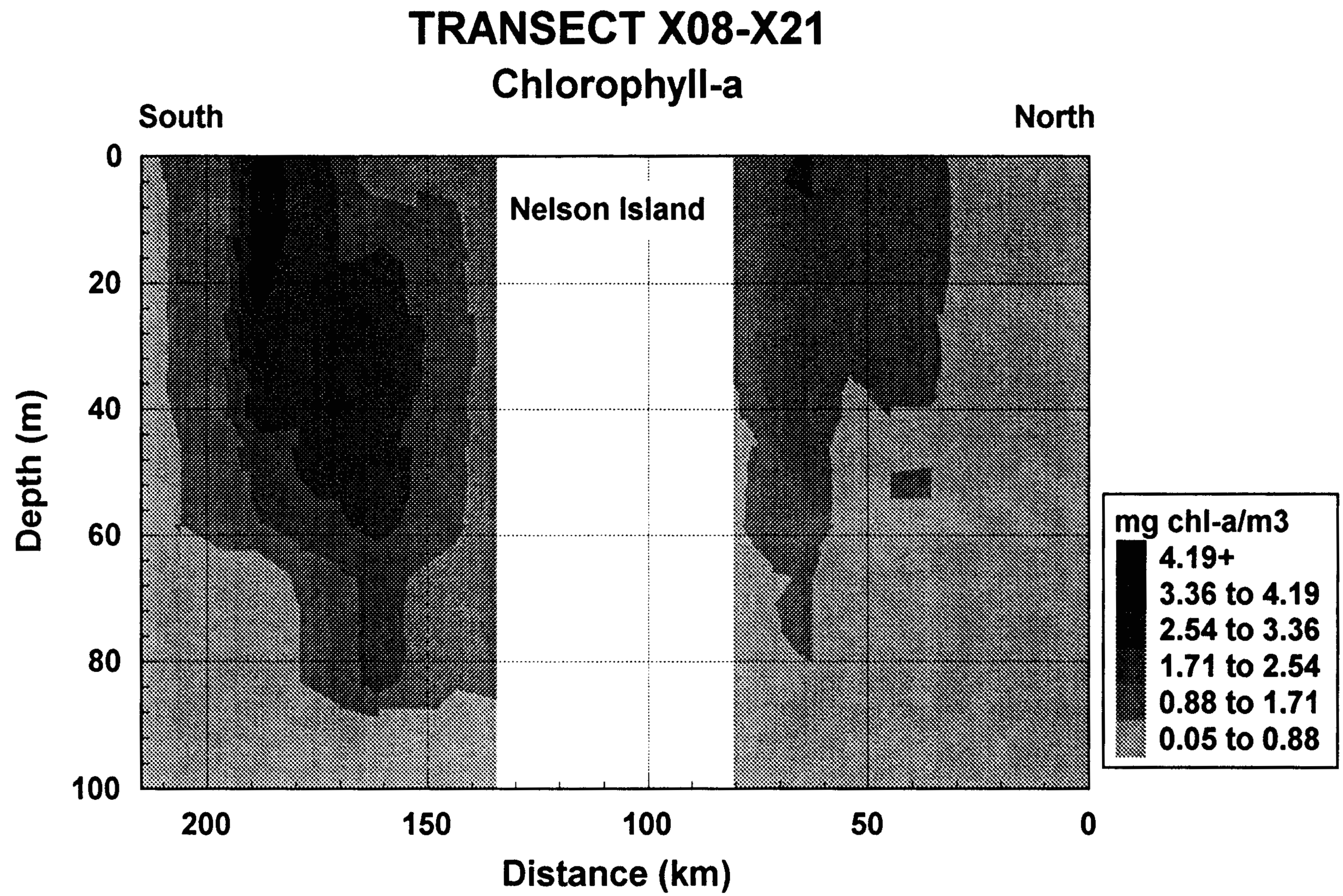


Figure 2.13 Distribution of chl-a (mg m^{-3}) in the upper 100m for the transect across Bransfield Strait (Stations X08-X21). The land mass between the two groups of stations is Nelson Island.

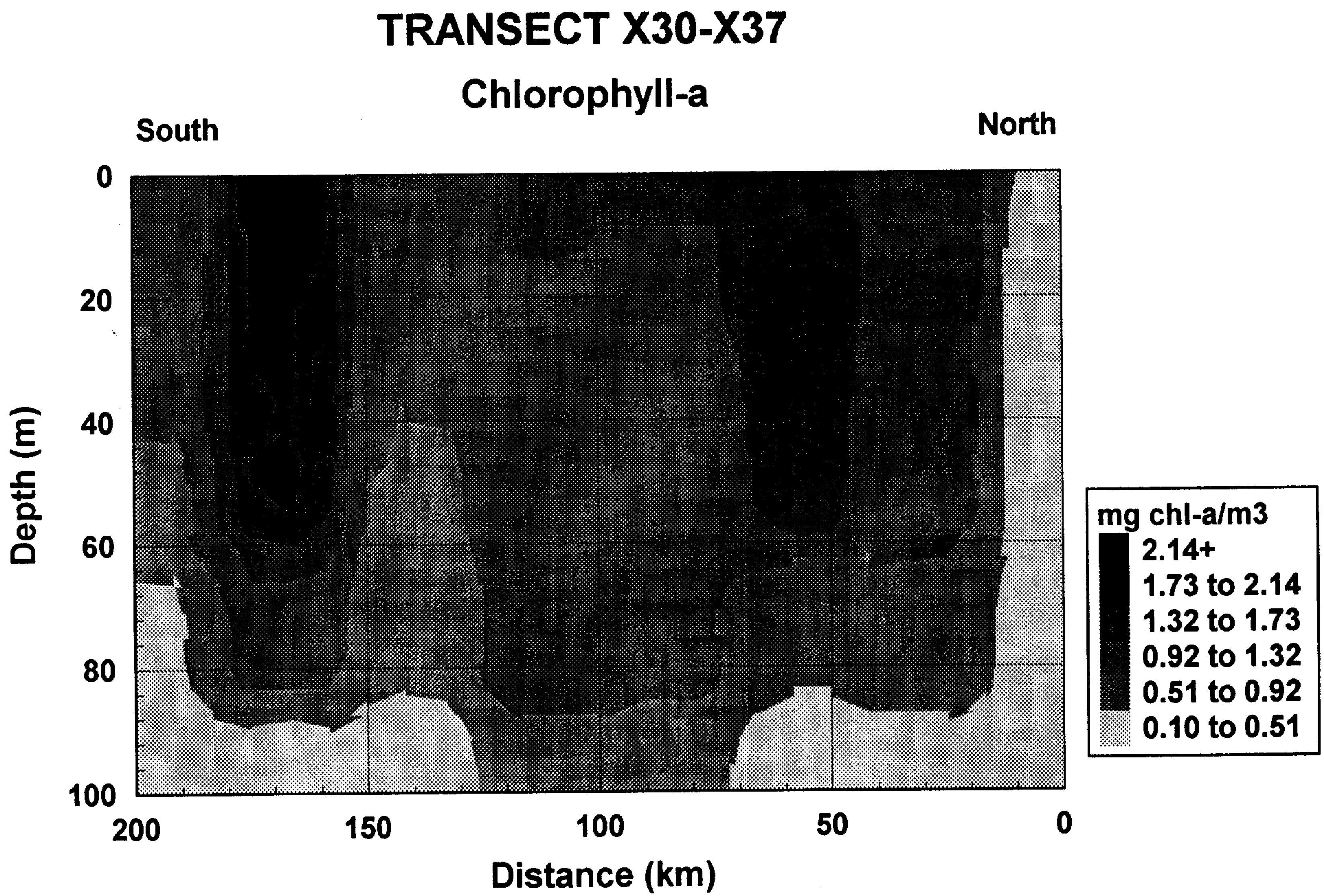


Figure 2.14 Distribution of chl-a (mg m^{-3}) in the upper 100m for the transect east of the large-area survey grid (Stations X30-X37).

3. Bioacoustic survey; submitted by David Demer (Leg I), Girish Chandran (Leg I), Jay Kirsch (Leg I), Roger Hewitt (Leg II), Nick Carbone (Leg II), and Jane Rosenberg (Leg II).

3.1 Objectives: The primary objectives of the bioacoustic survey were to map the meso-scale and micro-scale distributions of krill (*Euphausia superba*) in the vicinity of Elephant and Seal Islands; estimate their biomass; and determine their association with predators, bathymetry, water masses, phytoplankton, and light. Secondary goals included the acquisition of data to better define krill and salp (*Salpa thompsoni*) target strengths, diel migration patterns, swarm sizes, inter-swarm spacing, and survey optimization.

3.2 Methods and Accomplishments: An echo-integration system was used to map krill distributions and to quantify their abundances over three spatial scales within the AMLR study area: (1) Acoustic data were collected between each of the 91 stations occupied during the large-area surveys (Survey A and Survey D). (2) Two small-area acoustic surveys were conducted immediately north of Elephant Island (Survey B and Survey C). (3) Fine-scale acoustic sampling was conducted in the vicinity of a drogue and also in conjunction with directed MOCNESS sampling. In addition, acoustic data were collected during transects across the shelf-break north of Elephant and Nelson Islands, across Bransfield Strait, and across the Drake Passage.

The acoustic system was comprised of a Simrad EK500 echo-sounder outfitted with three transceiver/transducer subsystems, two Sun SparcStations for data logging and post-processing, the ship's MX200 GPS receiver, and an ethernet communication link. Redundancy was implemented into most system components for backup. Two hull-mounted transducers (approximately 5m deep), operating at 120 and 200kHz, were down-looking. The third transducer, deployed in a dead-weight towed body at 10-12m depth, operated at 120kHz and was oriented to be side-looking. All transducers were narrow beam with 7-9 degrees between half-power points. Pulses were transmitted once per second at 1kW for 0.3ms duration (120kHz) and 0.6ms duration (200kHz). Geographic positions were logged every 60 seconds. The insonified volumes were approximately conical and sampled to a depth of 250m for the down-looking transducers and to a range of 100m for the side-looking transducer. The Sun SparcStation was used for post-processing, including interpretation of echograms, echo-integration, target strength analyses, and contour mapping. The high volume acoustic data were processed and stored on 8.0 GB digital audio tapes (DAT).

Volume backscattering strength data were collected along all transects with breaks only for CTD stations. These data were integrated from 10 to 250m in depth and averaged over 0.1 n.mi. track-line increments. Frequency distributions of krill length were used to convert integrated volume backscattering strength to krill biomass density following the procedure outlined in Hewitt and Demer (1993).

Acoustic target strength (TS) measurements were made during IKMT and MOCNESS tows. These data will be used to develop TS versus krill and salp length relationships and to refine the relationship between volume backscattering and zooplankton biomass. These data will also be used to develop methods for discriminating backscatter from different taxa.

On two occasions, a surface water drogue was deployed in an area of high krill density and acoustic sampling was conducted within 1 n.mi. of the drogue over a 24-hour time period. The drogue consisted of a surface float with a radar reflector, strobe light, and radio beacon, and a sub-surface sea anchor deployed at approximately 10m (Experiment 1) and approximately 50m (Experiment 2). These data will be used to describe diel migration patterns of krill.

3.3 Tentative Conclusions: The 120 and 200kHz hull-mounted transducers (down-looking) were new this season and performed favorably with a high signal-to-noise ratio (SNR) in calm weather and acceptable SNR in most stormy conditions. Operations were stopped, however, during a severe storm (6-9m seas and 40-50 knot winds) when excessive ship motion and wave-injected bubbles caused a high noise level which degraded the data quality. The backup transducer was mounted in a dead-weight towed body. By orienting this transducer to be side-looking and deploying the towed body at 6-9 knots in moderate seas (during Surveys B and C, the drogue experiments, and the MOCNESS sampling), it was possible to detect krill in the upper 10m of the water column. System calibration, using standard spheres positioned beneath the transducers via outriggers and monofilament line, was successfully accomplished at the beginning and end of operations in Ezcurra Inlet, Admiralty Bay, King George Island. The beam patterns were mapped, and system gains were determined for each of the transducers.

The large-area surveys (Surveys A and D) were separated by approximately 5 weeks. During Survey A, the highest densities of krill were mapped north of King George Island (Figure 3.1). Lower densities were mapped south of King George Island, around Clarence and Gibbs Islands, and over a broad area northwest of Elephant Island. Scattering from salps, although many times less in magnitude, was more evenly distributed over the survey area than krill. During Survey D, highest densities of krill were mapped north of Elephant Island (Figure 3.2). Another possible area of high krill density was suggested at the far western end of the survey area north of King George Island. Lower densities were mapped south of Elephant Island and between Elephant and King George Islands. Salps were again distributed more evenly than krill over the survey area.

Two small-area surveys (Survey B and C) were conducted during the period between the large-area surveys. The purpose of these surveys was to better define the distribution patterns of krill within the foraging range of krill predators (chinstrap penguins and Antarctic fur seals) breeding on Seal Island. During both surveys, high densities of krill were mapped in the shoal waters to the north of Elephant Island (Figures 3.3 and 3.4). Additional areas of high krill densities were mapped in water greater than 1000m northwest of Elephant Island during Survey B, and north of Elephant Island during Survey C.

Krill biomasses for the portions of Surveys A and D centered over Elephant Island were estimated to be 401 x 10^3 and 359 x 10^3 tons, respectively (Table 3.1). Krill biomasses for Surveys B and C were estimated to be 87 x 10^3 and 97 x 10^3 tons, respectively. These values correspond to average krill density over the large-area survey of less than 10g/m^2 and over the small-area survey of less than 15g/m^2 during the austral summer of 1994. The average density for the large-area survey was the lowest observed during the last 5 years of AMLR surveys in the Elephant Island study area, and was approximately one-fifth of the 1990-1993 average density. Prior to this year's surveys, the lowest krill density in the Elephant Island area was observed during surveys conducted in 1991. The 1994 estimates should be considered preliminary, but additional refinements are not expected to alter the qualitative conclusion that krill biomass in the Elephant Island area was very low during 1994.

The side-looking 120kHz split-beam system provided conclusive evidence of krill migration into the surface waters circa local apparent midnight and then diving to deeper water during daylight hours. The behavioral patterns of dispersal during darkness and re-aggregation during daylight hours were also recorded.

Preliminary analyses of the target strength data indicate that the side-aspect target strengths of krill are higher in magnitude and less variable than their dorsal aspect counterparts.

3.4 Disposition of Data: Integrated volume backscattering data will be made available to other investigators in MS-DOS or UNIX (Sun-OS) format ASCII files. The analyzed echo-integration data, averaged over 0.1 n.mi. intervals, consumes approximately 10Mbtye. The data are available from David Demer, Southwest Fisheries Science Center, 8604 La Jolla Shores Drive, La Jolla, CA 92037.

3.5 Problems and Suggestions: Two improvements to *Surveyor* enhanced the field operations. The installation of a hull blister and two transducers improved overall signal-to-noise ratios of the system, provided additional capabilities, and greatly enhanced the efficiency of operations. Secondly, the removal of obsolete equipment and the addition of new cabinets and counter tops in the plot room and chart room provided a much improved and comfortable working environment.

The towing point for the towed body was moved from the aft deck to the bow, allowing it to be deployed forward of the turbulence from the ship's wake. Time-depth recordings indicated that 10-12m towing depths could be maintained over a wide range of towing speeds and sea states. By rotating the head of the towed body, side-looking and up-looking capabilities are possible.

The 12kHz Seabeam system continues to be a source of noise on both the 120kHz and 200kHz channels. Interference was registered as relatively high levels of volume backscattering over short range intervals that tended to drift in and out of the observation window. The interference introduced considerable bias when it coincided with krill aggregations. Data corruption was avoided by either shutting down the Seabeam system or by maintaining a close watch on the position of the interference and adjusting the timing between pings from the Seabeam system and the high-frequency system when necessary.

Future work should continue to be directed at the two principal sources of error in the use of echo-integration methodology for krill biomass assessment: (1) classification of acoustic targets, and (2) quantification of krill above the transducer.

3.6 References:

Hewitt, R.P. and D.A. Demer. 1993. Dispersion and abundance of Antarctic krill in the vicinity of Elephant Island in the 1992 austral summer. Mar. Ecol. Prog. Ser. 99:29-39.

Table 3.1 Summary of krill biomass estimates for 1994 surveys.

	Survey A	Survey B	Survey C	Survey D
Number of transects	8	12	12	9
Weighted mean density (g/m^2)	9.63	12.02	12.63	7.54
Weighted variance	1.06	1.12	8.05	4.38
Area ($x10^6$ m^2)	41,673	7,203	7,203	41,673
Biomass (ton)	401,346	86,594	96,926	358,948
CV (%)	0.11	0.09	0.22	0.25

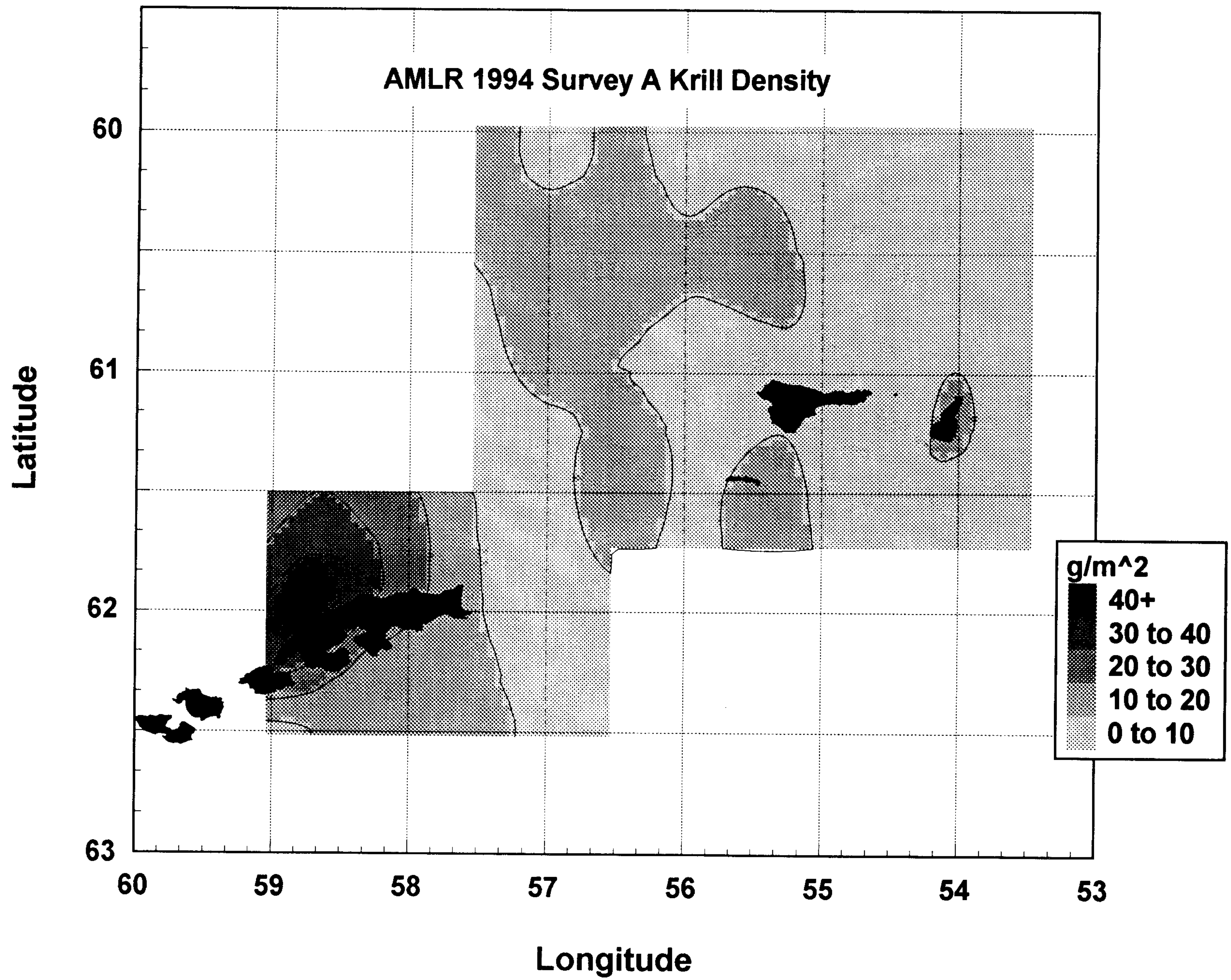


Figure 3.1 Spatial distribution of krill biomass density during Survey A.

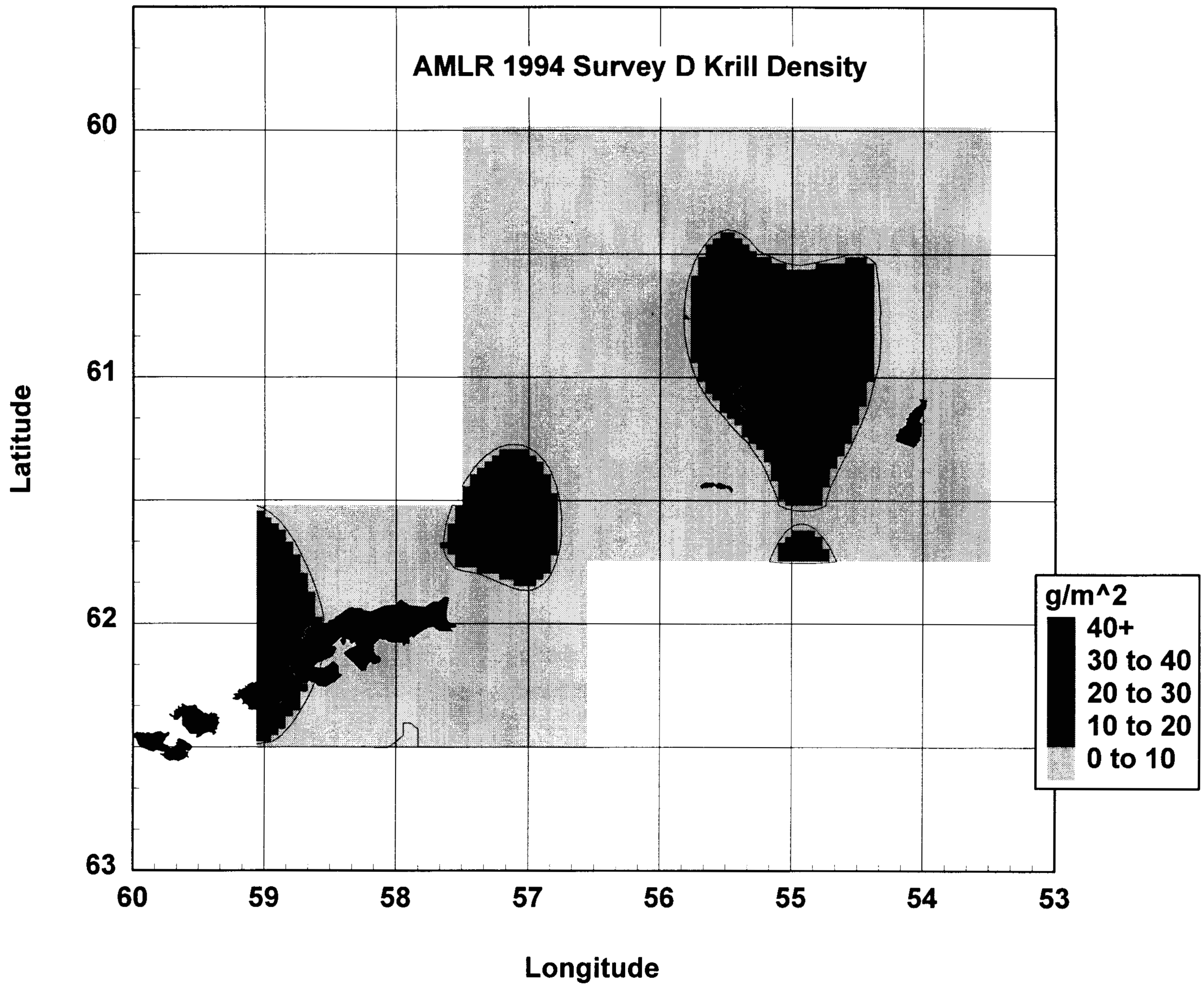


Figure 3.2 Spatial distribution of krill biomass density during Survey D.

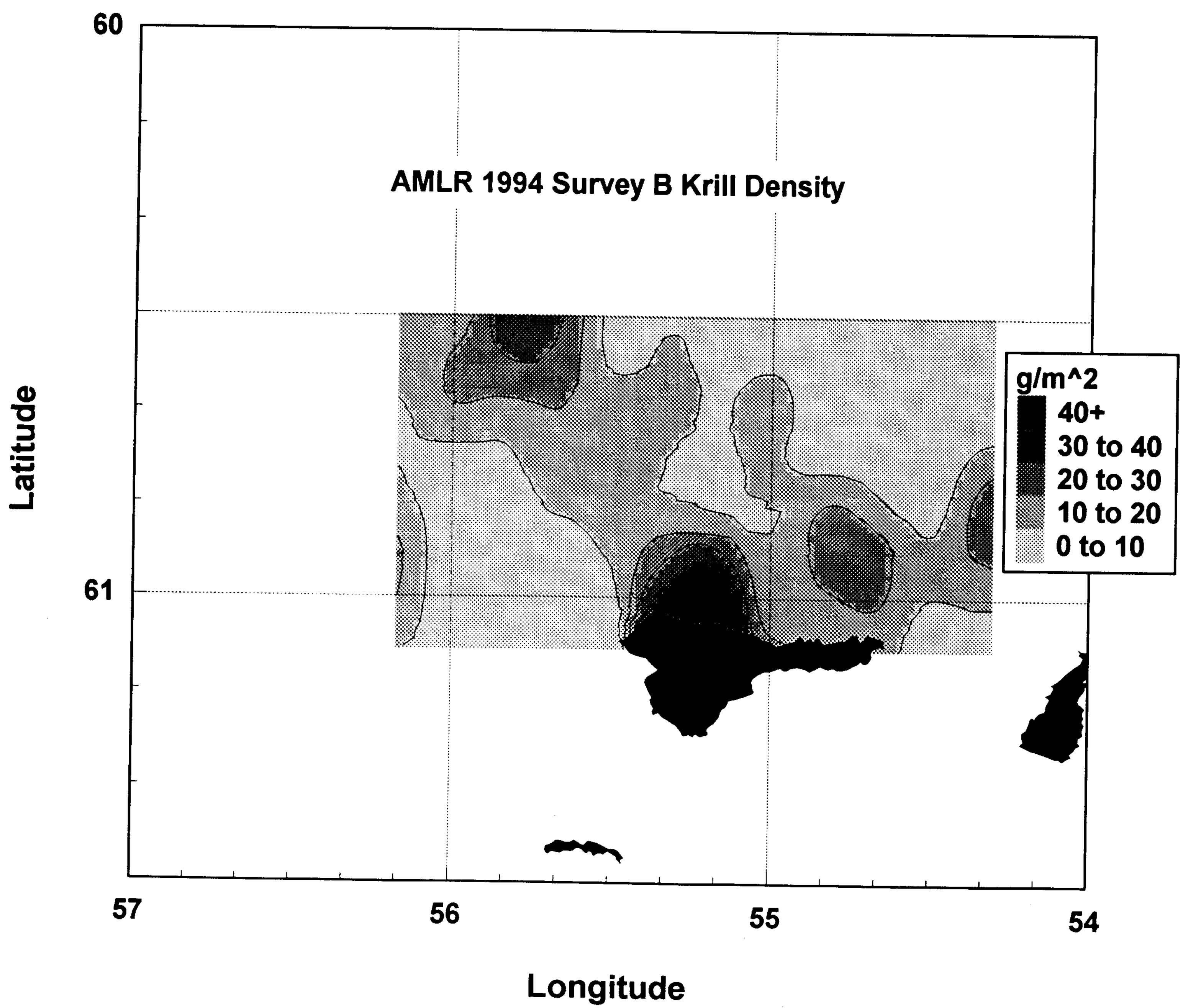


Figure 3.3 Spatial distribution of krill biomass density during Survey B.

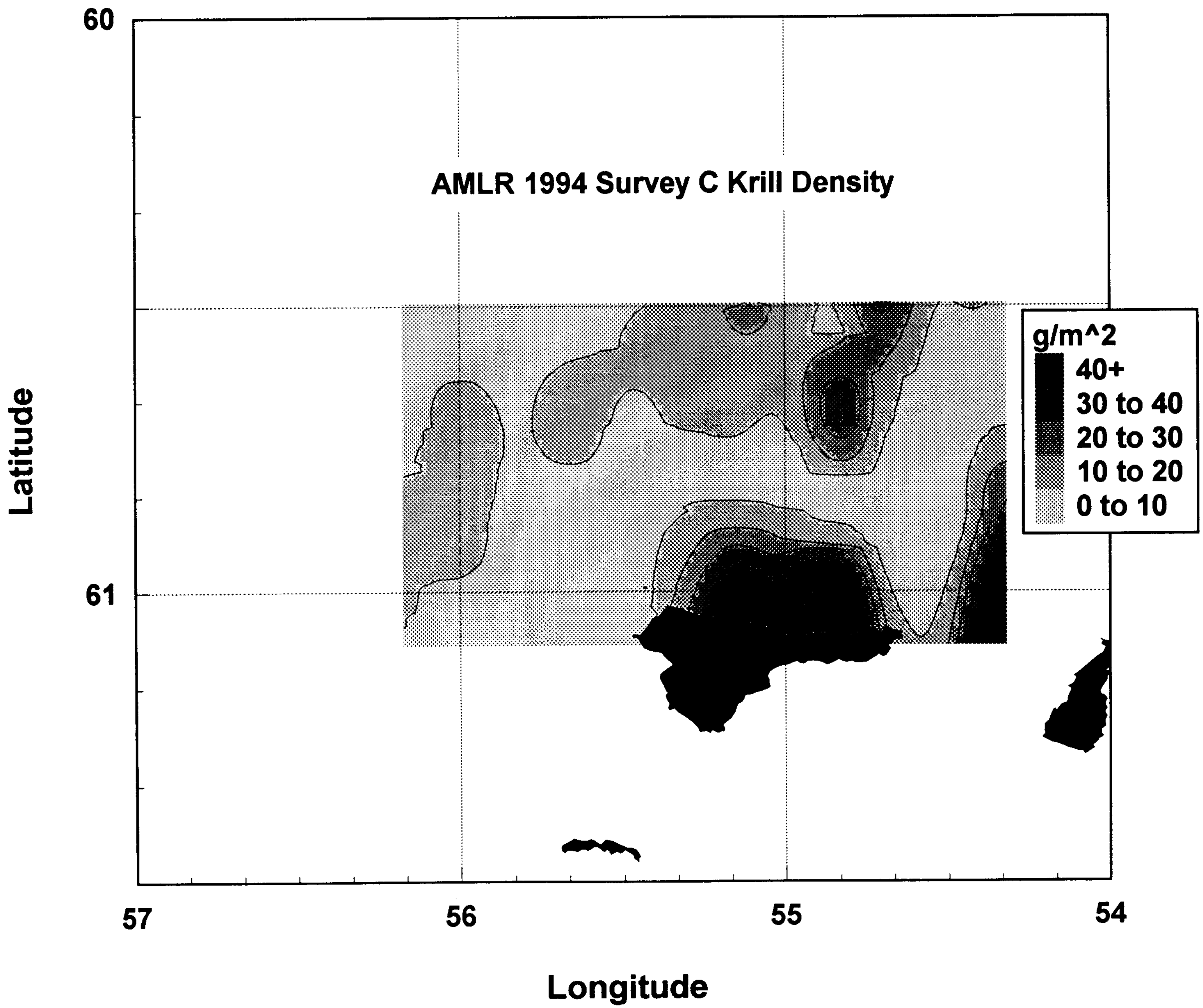


Figure 3.4 Spatial distribution of krill biomass density during Survey C.

4. Direct krill and zooplankton sampling; submitted by Valerie Loeb (Legs I and II), Volker Siegel (Leg I), Alan Young (Legs I and II), Mike Force (Legs I and II), David Greene (Leg I), Susan Kruse (Leg II), Rick Phleger (Leg I), Jennifer L. Quan (Leg II), Aaron Setran (Leg II), and Brian Walker (Leg I).

4.1 Objectives: The objective of this work was to provide information on the demographic structure of krill (*Euphausia superba*) and the distribution of macrozooplankton components in the AMLR study area. Essential demographic information for krill includes length, sex ratio, reproductive condition, and maturity stages. Information useful for determining the relationship between krill distribution and population structure and ambient environmental conditions was derived from net samples taken at the established CTD/rosette stations within the large-area surveys. Ancillary information on the abundance and distribution of other macrozooplankton components was also obtained from the large-area survey samples. Additional attention was focused on the distribution and abundance of salps (*Salpa thompsoni*) because of their potential influence on the distribution and behavior of krill and on acoustical biomass assessment.

4.2 Accomplishments: Krill and zooplankton were obtained from a 6-foot Isaacs-Kidd Midwater Trawl (IKMT) fitted with a 505µm mesh plankton net. Flow volumes were measured using a calibrated General Oceanics flowmeter mounted on the frame in front of the net mouth opening. All tows were fished obliquely to a depth of approximately 160m or to about 20m above bottom in shallower waters. Tow depths were derived from a Wildlife time-depth recorder.

In addition, targeted Multiple-Opening-Closing-Net-Environmental-Sensing-System (MOCNESS) tows were conducted to provide the acoustics program with information on the taxonomic composition, relative abundance, and size of organisms within discrete depth strata near the 200m depth contour of Elephant Island. This information is used for acoustic target identification and target strength calibration. A 1m^2 MOCNESS unit with eight 333µm mesh plankton nets was used; tows were performed in the upper 200m of the water column from evening twilight until morning twilight. Tow profile was dependent upon types and depths of acoustical signals at the time of sampling. Twelve tows were accomplished during the cruise, ten during Leg I and two during Leg II.

Shipboard Analyses: Krill collected by the IKMT tows were examined on board to provide information on the relative abundance and composition of stocks encountered during the large- and small-area surveys. The krill were removed and counted prior to sample preservation. All krill from samples containing <150 individuals were analyzed. For larger samples, a minimum of 100 individuals were measured, sexed, and staged. Total length (mm) was measured; stages were based on the classification scheme of Makarov and Denys (1981). Zooplankton samples of <1 liter were saved in their entirety; 1 liter subsamples were made of larger samples. These were preserved in 10% formalin for subsequent onboard analysis of the larger zooplankton constituents. After identification and enumeration of the larger constituents, all subsample material (minus salps) was returned to sample jars for long-term storage.

Abundance estimates of krill, salps, and other zooplankton are expressed here as numbers per m^2 and/or numbers per 1,000 m^3. Data are presented for the large-area surveys and for the more restricted "Elephant Island Area" (a box around Elephant Island) to allow comparison with previous AMLR cruises. Information on krill and salp abundance and krill size frequency distributions was derived from the targeted MOCNESS tows and presented to acoustics program personnel; these data will not be treated here.

4.3 Results and Preliminary Conclusions:

Leg I, Survey A.

Krill: A total of 81 non-targeted IKMT tows were made during the large-area survey of Leg I (Survey A) (Table 4.1A). Stations A02, A71, and A84 were not sampled because of poor weather conditions. Sixty-three of the 81 tows (78%) yielded 6,228 krill; 2,156 of these were measured, sexed and staged. Abundance in these tows ranged from 1 to 1,796 krill. The overall estimated mean abundance was $4.3m^{-2}$ (±13.4); the median value was $0.3m^{-2}$ (Table 4.1A). The catch sizes showed no obvious spatial pattern other than the larger catches occurred to the west and north of Elephant Island (Figure 4.1). The largest catch ($76m^{-2}$) was at station A47 to the northwest of Elephant Island.

The krill were dominated (77%) by reproductively mature stages. Juveniles and immature stages made up 4% and 19% of the total, respectively (Table 4.2). This maturity stage composition is reflected in the overall length frequency distribution which shows dominance (90%) by krill longer than 40mm (Figure 4.2). Over half of the individuals were 45-50mm. Females outnumbered males (Table 4.2). Most of the females (96%) were mature. The majority of these exhibited early (3b, 31%) and advanced (3c, 32%) ovarian development; fully gravid females (3d) were becoming more frequent during the latter portion of the sampling period. About half of the males (52%) were mature.

Cluster analysis applied to the length frequency distributions from all stations represented by >18 krill indicated some spatial differences in size and maturity stage composition across the survey area. This analysis resulted in two clusters. Both were dominated by the large, mature stages (Figures 4.3 and 4.4), but Cluster 1 included some juveniles (1+ age group) and greater proportions of immature stages (2+ age group). This is reflected in a secondary size mode of 20-30mm and greater proportions of 35-44mm krill in Cluster 1 compared to Cluster 2. Cluster 1 krill were primarily distributed in the waters adjacent to King George, Elephant, and Clarence Islands and between King George and Elephant Island. Cluster 2 krill were mostly distributed in Drake Passage waters to the north of the islands (Figure 4.5).

Zooplankton: Zooplankton were sorted and identified to species or the lowest level possible. Thirty-five species and taxonomic categories were identified (Table 4.3). Salps were the overall dominant form and were present in all samples. The maximum catch was 39.5 liters, with an estimated abundance of >4,700 salps per 1,000 m^3 (Table 4.4); the median catch was 4 liters and about 580 salps per 1,000 m^3. Largest salp concentrations occurred in the north-central and eastern portions of the survey area (Figure 4.6).

The euphausiid *Thysanoessa macrura* was the second most abundant species, present in 73 of the tows with a mean abundance of 80 per 1,000 m^3. Copepods and krill ranked third and fourth, respectively, in overall mean abundance (Table 4.3). Three amphipod species, *Vibilia antarctica*, *Themisto gaudichaudii*, and *Cyllopus magellanicus*, were quite frequent and relatively abundant in the samples. Larval fishes were rarely collected; the most abundant species were *Lepidonotothen larseni* and *L. kempi*.

Leg II, Cross-shelf Transects.

Krill and Salps: The 20 IKMT tows conducted during cross-shelf transects collected 1,947 krill (Table 4.5). Smallest sample sizes occurred in the Bransfield Strait (Figure 4.7), where six tows (Stations X08-X14) collected only 18 krill. Substantially larger krill catches were obtained north of King George Island (7 tows, Stations X15-X21; 977 krill; mean abundance 7.2m^{-2}) and Elephant Island (7 tows, Stations X22-X29; 952 krill; mean abundance 4.9m^{-2}). Krill were most abundant at the three innermost stations north of King George Island and at the stations over 500 and 1,500m bottom depths north of Elephant Island. Large (>45mm), mature krill dominated these catches. The overall mean krill abundance for the cross-shelf transects (4.3m^{-2}) was the same as for Survey A. The Bransfield Strait samples were characterized by low salp volumes (median of 1 liter per tow). Salp volume was moderate north of King George Island (1.5 liters median catch) and Elephant Island (4.5 liters median catch).

Leg II, Survey D.

Krill: A total of 4,788 krill were collected in 89 non-targeted IKMT tows made during Leg II's large-area survey (Survey D) (Table 4.1B). Krill were present in 60 of the tows (67%); however, 13 of these tows caught only one specimen each. The overall estimated mean abundance was 2.3m^{-2} (±8.2); the median value was 0.08m^{-2} (Table 4.1B). These values were about half of those from Survey A (Table 4.1A). The larger catches were clustered around and between King George and Elephant Islands (Figure 4.1). Largest catches (30-52m^{-2}) were made at Stations D28 and D29 between the islands and at D14 over the northwest shelf of King George Island.

Demographic analysis of the krill from Survey D was based on 1,489 individuals. Over 80% of these were reproductively mature; juveniles represented 5% and immature stages 14% (Table 4.2). In contrast to Survey A, males substantially outnumbered females (2.3:1 vs. 0.6:1; Table 4.2). The majority of the females were mature and without ovarian development (stages 3a and 3b, together 52%); fully gravid (3d, 15%) and recently spawned females (3e, 3%) were relatively more abundant than during Survey A. The majority of the males (86%) were mature.

Seventeen of the survey stations had sufficient quantities of krill (>20 individuals) to be used in cluster analysis of the length frequency distributions. This analysis resulted in two clusters, the composition of which was quite similar to the Survey A clusters (Figures 4.8 and 4.9).

Both were dominated by large, mature stages, but some juveniles (20-30mm lengths) and greater proportions of immature stages (35-44mm lengths) were represented in Cluster 1. Cluster 1 krill occurred in waters adjacent to King George, Elephant and Clarence Islands, while Cluster 2 krill were distributed in the area between King George and Elephant Islands (Figure 4.5).

Zooplankton: Thirty-four taxa were identified in the Survey D zooplankton samples (Table 4.3). Copepods comprised the most abundant category overall. Salps ranked second in abundance and were present in all but one of the samples. The maximum catch was 33.5 liters, with an estimated abundance of about 4,200 salps per 1,000 m^3 (Table 4.4). The median catch volume was slightly less than during Survey A (3.5 liters vs. 4 liters), but the median concentration (225 per 1,000 m^3) was only about half of that during the January survey. Salp concentrations of 100 to 1,000 per 1,000 m^3 were distributed across much of the survey area; smaller concentrations generally occurred in the northwest portion and larger concentrations were primarily located in the southwest and southeast portions (Figure 4.6).

Postlarval stages of the euphausiids *Thysanoessa macrura* and *Euphausia frigida* and larval euphausiids (predominantly *T. macrura*) followed salps in overall mean abundance. Krill ranked sixth in abundance (Table 4.3). Copepods, *E. frigida*, and euphausiid larvae were substantially more abundant, and *Clio pyramidata* and *Tomopteris carpenteri* were less abundant in Survey D compared to Survey A. Salps, *Vibilia antarctica* and krill showed moderate reductions in mean abundance between the two surveys. Because of identification difficulties and inconsistencies, comment cannot be made on the apparent abundance changes of the chaetognaths and *Cyllopus spp.*

"Elephant Island Area" and Between Year Comparisons: The median krill catch in the "Elephant Island Area" during the January and February-March sampling periods was notably lower than during corresponding periods in 1992 and 1993 (Table 4.4). Salp abundances (numbers and volume) during 1993 and 1994 were substantially higher than during 1992. However, there were differences in abundance characteristics between 1993 and 1994 that reflect between-year differences in (a) distribution patterns (e.g., patchiness) within each sampling period, and (b) seasonal abundance changes. A notable contrast between these two years was the abundance increase with advancing season in 1993 and abundance decrease in 1994. Peak abundance of the aggregate salp form typically occurs in February and is followed by a marked decline in March (Foxton 1966). This seasonal decrease in salp abundance was already underway late February to early March in 1994 but had not yet started at this time in 1993. In contrast to the other dominant species, the median abundance values for *Thysanoessa macrura* were quite similar across the three years.

Overall zooplankton diversity was lower in January 1994 compared to January 1993 (35 vs. 46 taxa). This was largely attributable to the absence of rarer, predominantly deep-living, taxa collected during 1993. The abundance and occurrence of several taxa (amphipods *Vibilia antarctica*, *Themisto gaudichaudii*, *Cyllopus magellanicus*, *C. lucasii* and *Hyperiella dilatata*; pteropod *Clio pyramidata*; polychaete worm *Tomopteris carpenteri*) were substantially greater than during the 1993 large-area surveys.

The overall krill length frequency distribution and maturity stage composition during the large-area surveys reflected low input of individuals from the last two year classes (1991/92 and 1992/93) and continued importance of the 1990/91 (3+) year class. The minor contributions by these two later year classes may in part explain this year's low krill abundance. Continued dominance by salps in 1994 may also be implicated in the low overall abundance and relatively uniform krill distributions (low median value) across the survey area, if (as speculated last year) large salp concentrations affect krill swarming behavior.

4.4 Disposition of Data and Samples: All of the krill demography data, salp, and other macrozooplankton data have been digitized and are available upon request from Loeb and Siegel. Data on the krill and salps collected in the targeted MOCNESS samples have been submitted to David Demer and Roger Hewitt (Southwest Fisheries Science Center). The krill and processed zooplankton (minus salps and larval fish) are stored at the Southwest Fisheries Science Center. The larval fishes will be included in the long term AMLR ichthyoplankton collection at Moss Landing Marine Laboratories (Loeb). Myctophids collected by the IKMT were preserved in alcohol or frozen and have been sent to the National Marine Mammal Laboratory (Seattle). Reference collections of krill developmental stages were prepared for scientists at the Southwest Fisheries Science Center (Rennie Holt) and National Marine Mammal Laboratory (Mike Schwartz and John Jansen).

4.5 Problems and Suggestions: The large-area survey is an extremely important component of the field sampling operations and should be conducted as thoroughly as possible with few, if any, stations not sampled due to poor weather conditions. The 13 days allocated to the large-area survey during Leg II proved sufficient to conduct net sampling operations at almost all of the stations. However, this survey was done under more or less benign weather conditions. In light of this, we recommend that 15 days be allocated for this survey each cruise leg to cover weather days. We also recommend that the large-area survey operations be conducted from east to west ("upstream") during both cruise legs so that stations or station lines abandoned due to prolonged periods of inclement weather may be sampled at a later time if possible.

The time-depth recorders once again proved to be unreliable. Of the two that were originally available, one was non-functional from the start and the other ceased to function after 40 net tows. This necessitated borrowing additional instruments from the Seal Island program for use during Leg II. In light of this, it would be desirable to have at least four electronic TDRs and to field test all instruments before the southbound transit. We strongly recommend that all TDRs be calibrated during shallow (to 250m) CTD casts before and during sampling operations each cruise leg. We also recommend that the winch metering device be calibrated prior to netting activities during each leg.

Shipboard analysis proved to be an effective way of assessing krill and larger zooplankton distribution patterns relative to hydrographic conditions in a more or less real-time manner and should be continued. The sample collection and processing operations went exceedingly well under the circumstances. The work teams included four people (two per watch) who conducted tows and gross sample processing, and three people who conducted krill and macrozooplankton analyses. This should be the standard for future AMLR operations. The continued high concentrations of salps across the survey area this year are notable. This animal warrants more detailed attention in future studies.

Standard and concise protocols must be established for macrozooplankton sample analysis to ensure consistency by the various work teams each field season. A more complete and concise set of taxonomic aids are required for this work.

4.6 Acknowledgments: The services performed by David Greene this past year were invaluable and should be continued in future AMLR operations. His services included renovation and modification of the plankton van, detailed attention to inventory and supplies, as well as maintenance and successful deployment of the MOCNESS.

4.7 References:

Foxton, P. 1966. The distribution and life history of *Salpa thompsoni Foxton*, with observations on a related species *Salpa gerlachei Foxton.* Discovery Report 34:1-116.

Makarov, R.R. and C.J.I. Denys. 1981. Stages of sexual maturity of *Euphausia superba.* BIOMASS Handbook 11. 13 pp.

TABLE 4.1 AMLR 1994 Large-area survey IKMT station information.

A. SURVEY A

STATION #	DATE	START TIME	END TIME	DIEL	TOW DEPTH(m)	BOTTOM DEPTH(m)	VOLUME (m3)	KRILL: TOTAL	#/M2	#/1000M3
A01	17/01/94	0010	0037	T	150	1537	3757	1	0.0	0.3
A03	17/01/94	0533	0607	D	136	293	6095	0	0.0	0.0
A04	17/01/94	0856	0934	D	190	1688	5287	2	0.1	0.4
A05	17/01/94	1208	1234	D	150	1852	2300	0	0.0	0.0
A06	17/01/94	1517	1543	D	138	1612	2765	1	0.0	0.4
A07	17/01/94	1826	1835	D	142	1981	3891	6	0.2	1.5
A08	17/01/94	2200	2207	T	40	150	810	0	0.0	0.0
A09	18/01/94	0236	0301	N	172	258	2789	3	0.2	1.1
A10	18/01/94	0546	0620	D	164	890	4302	11	0.4	2.6
A11	18/01/94	0840	0911	D	152	983	4351	32	1.1	7.4
A12	18/01/94	1527	1549	D	161	1033	2697	14	0.8	5.2
A13	18/01/94	1830	1850	D	120	282	2446	1	0.0	0.4
A14	18/01/94	2144	2155	T	76	185	1660	1	0.0	0.6
A15	19/01/94	0023	0045	N	140	320	2743	1	0.1	0.4
A16	19/01/94	0444	0510	D	120	6741	3669	1	0.0	0.3
A17	19/01/94	1104	1130	D	126	356	3616	3	0.1	0.8
A18	19/01/94	1508	1538	D	146	685	4201	16	0.6	3.8
A19	19/01/94	1824	1841	D	168	1200	1693	5	0.5	3.0
A20	19/01/94	2159	2224	T	151	1120	2252	47	3.2	20.9
A21	20/01/94	0115	0135	N	156	1649	2712	1	0.1	0.4
A22	20/01/94	0453	0514	T	169	1500	2232	0	0.0	0.0
A23	20/01/94	0846	0924	D	187	2081	4642	36	1.5	7.8
A24	20/01/94	1256	1320	D	157	1640	2807	15	0.8	5.3
A25	20/01/94	1652	1715	D	199	1326	2639	1	0.1	0.4
A26	21/01/94	0607	0633	D	130	2000	2686	2	0.1	0.7
A27	21/01/94	0907	0934	D	168	1901	3311	18	0.9	5.4
A28	21/01/94	1205	1229	D	149	1485	3266	77	3.5	23.6
A29	21/01/94	1519	1554	D	192	2857	4621	39	1.6	8.4
A30	21/01/94	1845	1916	D	159	1681	4145	8	0.3	1.9
A31	21/01/94	2152	2220	T	195	483	2492	0	0.0	0.0
A32	22/01/94	0108	0133	N	232	410	2479	361	33.8	145.6
A33	22/01/94	0409	0435	N	132	631	3807	4	0.1	1.1
A34	22/01/94	0714	0739	D	156	1600	3401	0	0.0	0.0
A35	22/01/94	1102	1125	D	150	1654	2576	0	0.0	0.0
A36	22/01/94	1404	1430	D	151	542	3597	0	0.0	0.0
A37	22/01/94	1656	1721	D	175	500	2734	556	35.6	203.4
A38	22/01/94	1947	2015	D	138	480	3781	185	6.8	48.9
A39	22/01/94	2252	2320	T	141	2180	3369	141	5.9	41.9
A40	23/01/94	0203	0220	N	169	2000	4578	629	23.2	137.4
A41	23/01/94	0530	0558	D	154*	3946	3255	76	3.6	23.3
A42	23/01/94	0842	0909	D	154*	3804	3843	27	1.1	7.0
A43	23/01/94	1153	1219	D	154*	3667	3546	10	0.4	2.8
A44	23/01/94	1500	1523	D	154*	3713	2915	22	1.2	7.5
A45	23/01/94	1800	1824	D	154*	3811	3659	7	0.3	1.9
A46	23/01/94	2107	2131	T	154*	3888	3774	63	2.6	16.7
A47	24/01/94	0005	0031	N	154*	1432	3622	1796	76.4	495.9
A48	24/01/94	0250	0311	T	154*	304	3009	2	0.1	0.7
A49	24/01/94	0520	0536	D	80*	170	1931	1	0.0	0.5

TABLE 4.1 AMLR 1994 Large-area survey IKMT station information.

STATION #	DATE	START TIME	END TIME	DIEL	TOW DEPTH(m)	BOTTOM DEPTH(m)	VOLUME (m3)	KRILL: TOTAL	#/M2	#/1,000M3
A50	24/01/94	0800	0826	D	154*	392	3211	0	0.0	0.0
A51	24/01/94	1050	1124	D	154*	801	3690	377	15.7	102.2
A52	24/01/94	1348	1410	D	154*	2232	2747	0	0.0	0.0
A53	24/01/94	1650	1713	D	154*	540	2567	0	0.0	0.0
A54	24/01/94	1935	1940	D	30*	60	587	0	0.0	0.0
A55	24/01/94	2225	2232	D	35*	70	730	12	0.6	16.4
A56	25/01/94	0118	0144	N	154*	1025	2785	0	0.0	0.0
A57	25/01/94	0439	0508	T	154*	3618	3370	15	0.7	4.5
A58	25/01/94	0805	0830	D	154*	3530	2987	19	1.0	6.4
A59	25/01/94	1115	1140	D	154*	3582	3407	13	0.6	3.8
A60	25/01/94	1428	1447	D	154*	3592	2323	10	0.7	4.3
A61	25/01/94	1719	1742	D	154*	3385	2739	4	0.2	1.5
A62	25/01/94	2011	2036	D	154*	3425	2875	39	2.1	13.6
A63	25/01/94	2310	2332	N	154*	3100	2613	90	5.3	34.4
A64	26/01/94	0142	0157	N	154*	300	1502	716	73.4	476.7
A65	26/01/94	0616	0632	D	154*	186	1926	6	0.5	3.1
A66	26/01/94	0906	0932	D	154*	633	2460	0	0.0	0.0
A67	26/01/94	1216	1235	D	154*	2087	2528	6	0.4	2.4
A68	26/01/94	1459	1514	D	154*	817	1649	4	0.4	2.4
A69	26/01/94	1745	1807	D	154*	1586	2883	4	0.2	1.4
A70	26/01/94	2031	2056	D	154*	530	3910	0	0.0	0.0
A72	27/01/94	0227	0242	N	154*	3000	1646	0	0.0	0.0
A73	27/01/94	0526	0549	D	154*	3500	2733	15	0.8	5.5
A74	27/01/94	0827	0851	D	154*	3090	3238	9	0.4	2.8
A75	27/01/94	1124	1149	D	154*	3250	3362	15	0.7	4.5
A76	27/01/94	1429	1454	D	154*	3094	3459	39	1.7	11.3
A77	27/01/94	1733	1804	D	154*	2738	4265	48	1.7	11.3
A78	27/01/94	2036	2054	D	154*	3043	1893	0	0.0	0.0
A79	27/01/94	2346	0008	N	154*	2238	2294	562	37.7	245.0
A80	28/01/94	0251	0311	N	154*	1158	2379	1	0.1	0.4
A81	28/01/94	0558	0621	D	154*	1258	2230	0	0.0	0.0
A82	28/01/94	0909	0934	D	154*	780	3197	1	0.0	0.3
A83	28/01/94	1200	1218	D	154*	335	2783	1	0.1	0.4

SURVEY A AREA	NO.	81	6228		
	MEAN			4.3	27.1
	STD			13.4	84.2
	MEDIAN			0.3	1.9
ELEPHANT ISLAND AREA	NO.	63	6150		
	MEAN			5.5	34.5
	STD			14.9	94.2
	MEDIAN			0.5	3.1

*Tow depths for stations A41-A83 are based on averaged values from previous stations with similar MWO and wire angles.

TABLE 4.1 AMLR 1994 Large-area survey IKMT station information.

B. SURVEY D

STATION #	DATE	START TIME	END TIME	DIEL	TOW DEPTH(m)	BOTTOM DEPTH(m)	VOLUME (m3)	KRILL: TOTAL	#/M2	#/1000M3
D01	09/03/94	0502	0527	T	132	1550	3543.6	0	0.00	0.00
D02	09/03/94	0205	0227	N	186	1600	2476.5	8	0.60	3.23
D03	08/03/94	2328	2340	N	133	486	1093.2	0	0.00	0.00
D04	08/03/94	1256	1311	D	154	1400	1724.9	0	0.00	0.00
D05	08/03/94	0848	0914	D	147	1855	3649.2	4	0.16	1.10
D06	08/03/94	0555	0625	T	145	1540	4256.4	6	0.20	1.41
D07	08/03/94	0303	0323	N	136	1900	3914.5	16	0.56	4.09
D08	08/03/94	0016	0036	N	126	240	2645.2	28	1.33	10.59
D09	07/03/94	1933	1953	D	182	247	2625.2	51	3.54	19.43
D10	07/03/94	1644	1712	D	159	982	3958.0	0	0.00	0.00
D11	07/03/94	1351	1417	D	127	2400	4876.0	1	0.03	0.21
D12	07/03/94	1015	1036	D	150	1027	3470.4	0	0.00	0.00
D13	07/03/94	0711	0731	D	101	289	3392.0	3	0.09	0.88
D14	07/03/94	0340	0358	N	76	158	2335.2	929	30.23	397.83
D15	07/03/94	0106	0121	N	141	330	1360.6	14	1.45	10.29
D16	06/03/94	2203	2225	N	150	2100	3817.8	13	0.51	3.41
D17	06/03/94	1550	1617	D	171	353	3404.5	1	0.05	0.29
D19	06/03/94	1024	1045	D	148	2657	3449.1	1	0.04	0.29
D20	06/03/94	0725	0749	D	159	4127	3899.5	1	0.04	0.26
D21	06/03/94	0424	0450	N	144	4683	4194.4	10	0.34	2.38
D22	06/03/94	0104	0139	N	146	3700	3948.7	5	0.18	1.27
D23	05/03/94	2209	2224	N	130	1589	3396.7	0	0.00	0.00
D24	05/03/94	1857	1921	D	163	3902	3219.5	0	0.00	0.00
D25	05/03/94	1606	1632	D	207	3581	3563.3	0	0.00	0.00
D27	05/03/94	0730	0750	D	166	2834	2732.1	0	0.00	0.00
D28	05/03/94	0430	0445	N	128	3683	2295.9	846	47.17	368.48
D29	05/03/94	0123	0142	N	140	2187	3883.1	1441	51.95	371.10
D30	04/03/94	2218	2241	N	157	1740	3492.0	270	12.14	77.32
D31	04/03/94	1919	1943	D	141	4820	3097.3	0	0.00	0.00
D32	04/03/94	1629	1650	D	163	400	2574.4	1	0.06	0.39
D33	04/03/94	1344	1409	D	163	600	4190.4	1	0.04	0.24
D34	04/03/94	1045	1105	D	111	1600	3140.1	2	0.07	0.64
D35	04/03/94	0700	0725	N	210	1730	3170.6	15	0.99	4.73
D36	04/03/94	0404	0430	N	141	526	4049.4	34	1.18	8.40
D37	04/03/94	0121	0245	N	147	510	3475.3	113	4.78	32.52
D38	03/03/94	2223	2245	N	136	378	2979.0	52	2.37	17.46
D39	03/03/94	1949	2013	T	136	2187	3476.9	1	0.04	0.29
D40	03/03/94	1700	1726	D	158	2618	4006.9	0	0.00	0.00
D41	03/03/94	1408	1431	D	156	3800	3189.8	0	0.00	0.00
D42	03/03/94	1110	1134	D	201	3888	2783.5	0	0.00	0.00
D43	03/03/94	0825	0845	D	179	3689	2826.5	0	0.00	0.00
D44	03/03/94	0520	0545	T	132	3712	3554.0	3	0.11	0.84
D45	03/03/94	0220	0252	N	163	3800	3244.2	2	0.10	0.62
D46	02/03/94	2322	2344	N	157	3800	3046.6	0	0.00	0.00
D47	02/03/94	2044	2101	T	155	3509	2306.9	0	0.00	0.00
D48	02/03/94	1747	1807	D	177	288	2698.2	1	0.07	0.37
D49	02/03/94	1502	1521	D	109	183	2718.9	1	0.04	0.37
D50	02/03/94	1225	1247	D	167	307	3225.9	3	0.16	0.93

TABLE 4.1 AMLR 1994 Large-area survey IKMT station information.

STATION #	DATE	START TIME	END TIME	DIEL	TOW DEPTH(m)	BOTTOM DEPTH(m)	VOLUME (m3)	KRILL: TOTAL	#/M2	#/1000M3
D51	02/03/94	0930	0955	D	202	840	2704.6	32	2.39	11.83
D52	02/03/94	0615	0645	D	162	2080	3413.0	2	0.09	0.59
D53	02/03/94	0329	0345	N	81	512	2145.5	0	0.00	0.00
D54	02/03/94	0050	0054	N	35	62	530.8	3	0.20	5.65
D55	01/03/94	2112	2121	N	67	88	1209.1	101	5.60	83.53
D56	01/03/94	1824	1848	D	149	3308	3793.5	439	17.24	115.72
D57	01/03/94	1528	1555	D	155	3600	3434.6	0	0.00	0.00
D58	01/03/94	1216	1237	D	164	3500	2816.6	1	0.06	0.36
D59	01/03/94	0913	0932	D	176	3488	2058.6	0	0.00	0.00
D60	01/03/94	0550	0620	D	172	3595	3822.5	0	0.00	0.00
D61	01/03/94	0256	0320	N	171	3300	3531.2	0	0.00	0.00
D62	28/02/94	2344	0014	N	134	3400	4582.3	4	0.12	0.87
D63	28/02/94	2041	2106	N	179	3187	3347.4	55	2.94	16.43
D64	28/02/94	1739	1802	D	153	307	3126.4	38	1.86	12.15
D65	28/02/94	1300	1322	D	137	180	2728.3	13	0.65	4.76
D66	28/02/94	1020	1042	D	107	644	4091.6	2	0.05	0.49
D67	28/01/94	0710	0736	D	140	2080	3278.6	62	2.65	18.91
D68	28/02/94	0417	0443	N	173	707	3748.1	1	0.05	0.27
D69	28/02/94	0125	0154	N	180	1589	3163.7	74	4.21	23.39
D70	27/02/94	2240	2301	N	173	628	3226.8	3	0.16	0.93
D71	27/02/94	1948	2013	D	129	600	4925.6	20	0.52	4.06
D72	27/02'94	1657	1720	D	182	2887	3370.8	1	0.05	0.30
D73	27/02/94	1401	1424	D	142	3200	3674.2	13	0.50	3.54
D74	27/02/94	1102	1124	D	146	3088	3269.8	1	0.04	0.31
D75	27/02/94	0800	0828	D	150	3246	3243.7	0	0.00	0.00
D76	27/02/94	0510	0537	T	150	3023	4815.5	0	0.00	0.00
D77	27/02/94	0158	0228	N	164	2800	4772.9	0	0.00	0.00
D78	26/02/94	2246	2311	N	138	3025	3747.5	4	0.15	1.07
D79	26/02/94	1937	2006	T	152	1502	4579.4	0	0.00	0.00
D80	26/02/94	1630	1657	D	131	1200	3449.2	0	0.00	0.00
D81	26/02/94	1323	1348	D	150	1300	3354.3	17	0.76	5.07
D82	26/02/94	1017	1043	D	180	798	3564.2	5	0.25	1.40
D83	26/02/94	0715	0740	D	142	340	3538.1	0	0.00	0.00
D84	26/02/94	0426	0455	T	111	540	5014.5	6	0.13	1.20
D85	26/02/94	0141	0200	N	146	646	2323.1	2	0.13	0.86
D86	25/02/94	2244	2306	N	127	1054	3322.5	2	0.08	0.60
D87	25/02/94	1936	2002	D	148	1892	4072.5	4	0.15	0.98
D88	25/02/94	1617	1646	D	172	584	4261.4	0	0.00	0.00
D89	25/02/94	1328	1353	D	138	2500	4178.2	0	0.00	0.00
D90	25/02/94	1017	1045	D	160	2396	4545.5	3	0.11	0.66
D91	25/02/94	0705	0744	D	224	3313	4783.4	3	0.14	0.63
SURVEY D AREA						NO.	89	4788		
						MEAN			2.3	18.6
						STD			8.2	69.6
						MEDIAN			0.08	0.6
ELEPHANT ISLAND AREA						NO.	70	3697		
						MEAN			2.3	17.1
						STD			8.5	63.5
						MEDIAN			0.06	0.4

Table 4.2 Maturity stage composition of krill collected in the large survey areas and Elephant Island area during 1994 compared to the Elephant Island area during 1992 and 1993.

	E. superba January				*E. superba* February-March			
Area	1994 Survey A	1994 Elephant I.	1993 Elephant I.	1992 Elephant I.	1994 Survey D	1994 Elephant I.	1993 Elephant I.	1992 Elephant I.
	%	%	%	%	%	%	%	%
Juveniles	4.0	4.0	7.2	37.1	5.3	3.7	3.5	33.6
Immature stages	18.8	18.8	30.7	19.1	14.2	6.2	51.4	27.1
Mature stages	77.2	77.2	62.2	43.9	80.5	90.1	45.1	39.2
Females:								
F2	2.4	2.3	7.8	0.8	4.8	0.7	21.8	0.8
F3a	17.9	18.0	11.7	0.6	7.1	3.5	12.4	10.3
F3b	19.2	19.3	14.3	12.2	7.6	7.8	6.2	10.2
F3c	19.9	20.1	5.1	9.2	3.9	4.3	3.7	4.3
F3d	2.3	2.3	1.2	0.4	4.2	4.6	1.1	1.2
F3e	0.0	0.0	0.0	0.0	0.8	0.9	1.2	<0.1
Males:								
M2a	0.3	0.3	6.8	8.7	0.6	0.2	6.9	4.3
M2b	9.3	9.4	11.9	7.3	3.7	1.2	19.1	19.8
M2c	6.8	6.8	4.2	2.3	5.1	4.2	3.6	2.24
M3a	4.3	4.3	3.7	2.8	20.2	24.1	2.1	2.49
M3b	13.5	13.2	26.2	18.7	36.7	44.7	18.4	10.7
Male:Female ratio	0.6:1	0.5:1	1.3:1	1.7:1	2.3:1	3.4:1	1.1:1	1.5:1
No. measured	2156	2078	4283	2472	1489	1155	3669	3646

Table 4.3 Zooplankton taxa present in the large survey area samples during 1994 compared to 1993. F is frequency of occurrence (%) in tows. n.a. indicates taxa present but not enumerated.

	Survey A January 1994		Survey D February-March 1994		Survey A January 1993		Survey E February-March 1993	
Taxon	F (81 tows)	Mean #/1000 m3	F (89 tows)	Mean #/1000 m3	F (87 tows)	Mean #/1000 m3	F (80 tows)	Mean #/1000 m3
Salpa thompsoni	100.0	818.3	98.9	523.5	100.0	1001.5	100.0	1567.1
Vibilia antarctica	98.8	11.8	85.4	6.4	64.4	1.6	47.5	1.6
Thysanoessa macrura	90.0	79.7	91.0	118.9	95.4	51.5	96.3	141.5
Themisto gaudichaudii	83.8	10.6	94.4	11.8	50.6	0.8	60.0	2.3
Cyllopus magellanicus	82.5	6.3	79.8	4.4	18.4	0.5	32.5	0.9
Euphausia superba	77.5	27.1	66.3	18.4	90.8	44.1	83.8	35.0
Clio pyramidata	40.0	5.4	9.0	0.2	6.9	0.2	1.3	0.0
Tomopteris carpenteri	37.5	2.5	24.7	0.6	33.3	0.5	12.5	0.2
Copepoda	30.0	41.3	89.9	3090.2	31.0	38.1	n.a.	n.a.
*Eukronia hamata**	21.3	0.2	3.4	0.1	n.a.	n.a.	n.a.	n.a.
Sagitta gazellae*	20.0	0.4	34.8	3.8	n.a.	n.a.	n.a.	n.a.
Chaetognatha*	—	—	n.a.	n.a.	56.3	9.2	n.a.	n.a.
Diphyes antarctica	20.0	0.3	13.5	0.1	20.7	0.5	15.0	0.3
Hyperiella dilatata	18.7	0.3	36.0	0.6	6.9	0.0	1.3	0.0
Euphausia frigida	17.5	3.8	61.8	25.9	26.4	3.6	7.5	1.0
Cyllopus lucasii	16.3	0.7	89.9	6.1	11.5	0.4	37.5	1.5
Beroe cucumis	15.0	0.1	2.2	0.0	2.3	0.0	1.3	0.0
Clione limacina	13.8	0.3	—	—	4.6	0.1	—	—
Spongiobranchaea australis	11.3	0.1	14.6	0.1	40.2	0.6	20.0	0.3
Euphausia triacantha	7.5	1.2	11.2	1.0	25.3	1.0	21.3	1.0
Dimophyes arctica	7.5	0.0	10.1	0.0	3.4	0.0	6.3	0.2
Lepidonotothen larseni (larvae)	6.3	0.7	—	—	16.1	0.2	5.0	0.2
Primno macropa	6.3	0.5	10.1	0.1	3.4	0.0	—	—
Limacina helicina	6.3	0.3	—	—	—	—	—	—
Lepidonotothen kempi (larvae)	6.3	0.3	6.7	0.1	5.7	0.1	1.3	0.0
Heteropoda (pteropod) sp.	2.5	0.0	—	—	—	—	—	—
Electrona antarctica (larvae)	2.5	0.0	11.2	0.2	2.3	0.0	5.0	0.1
Electrona antarctica (adults)	2.5	0.0	13.5	0.1	10.3	0.0	3.8	0.0
Vanadis antarctica	2.5	0.0	7.9	0.1	4.6	0.0	—	—
Krefftichthys anderssoni (juv.)	2.5	0.0	—	—	—	—	—	—
Lepidonotothen nudifrons (larvae	1.3	0.2	—	—	1.1	0.1	—	—
Calycopsis borchgrevinki	1.3	0.0	10.1	0.1	1.1	0.0	11.3	0.1
Notothenia coriiceps (juv.)	1.3	0.0	—	—	—	—	—	—
Orchomene plebs	1.3	0.0	2.2	0.1	3.4	0.1	—	—
Scyphomedusae sp. 1	1.3	0.0	—	—	2.3	0.0	1.3	0.0
Hyperia macrocephala	1.3	0.0	—	—	1.1	0.4	—	—
Notolepis sp. (larvae)	—	—	5.6	0.0	12.6	0.1	3.8	0.1
Periphylla periphylla	—	—	3.4	0.0	4.6	0.0	—	—
Fish eggs	—	—	7.9	0.1	—	—	—	—
Hyperoche medusarum	—	—	5.6	0.1	—	—	—	—
Beroe forskalii	—	—	3.4	0.1	1.1	0.0	—	—
Sipunculid	—	—	3.4	0.0	—	—	—	—
Gymnoscopelus sp. (Adult)	—	—	2.2	0.0	—	—	—	—
Cephalopoda	—	—	1.1	0.0	—	—	—	—
Eusirus microps	—	—	—	—	2.3	0.0	1.3	0.0
Travisiopsis levinseni	—	—	—	—	2.3	0.0	—	—
Chionodraco rastrospinosus (lar	—	—	—	—	2.3	0.0	—	—
Scyphomedusae sp. 4	—	—	—	—	2.3	0.0	—	—
Hyperiella antarctica	—	—	—	—	2.3	0.0	—	—
Cyphocaris richardi	—	—	—	—	1.1	0.0	—	—
Scyphomedusae sp. 3	—	—	—	—	1.1	0.0	—	—
Chaenodraco wilsoni (larva)	—	—	—	—	1.1	0.0	—	—
Scyphomedusae sp. 2	—	—	—	—	1.1	0.0	—	—
Decapoda sp. (larva)	—	—	—	—	1.1	0.0	—	—
Atolla wyvillei	—	—	—	—	1.1	0.0	—	—
Hyperiella macronyx	—	—	—	—	1.1	0.0	—	—
Euphausia crystallorophias	—	—	—	—	1.1	0.0	5.0	0.2

* All chaetognath species, including E. hamata and S. gazellae, were combined as one category in 1993.

Table 4.4 Abundance of krill and dominant zooplankton species collected in the large-area surveys and "Elephant Island Area" during (A) January 1994 and (B) February-March 1994, compared to similar sampling periods in 1992 and 1993. Zooplankton data are not available for February-March 1992.

A.	January											
	E. superba				*T. macrura*				*S. thompsoni*			
	1994	1994	1993	1992	1994	1994	1993	1992	1994	1994	1993	1992
Area	Survey A	Elephant I.	Elephant I.	Elephant I.	Survey A	Elephant I.	Elephant I.	Elephant I.	Survey A	Elephant I.	Elephant I.	Elephant I.
No. Tows	81	63	70	63	81	63	70	63	81	63	70	63
Abundance: No./1000 m3												
Median	1.9	3.1	8.2	5.7	33.6	25.4	27.5	22.5	512.2	582.3	245.8	14.0
Mean	27.1	34.5	28.8	23.7	79.7	74.6	48.6	48.1	818.1	931.9	1213.4	94.3
Std. Dev.	84.2	94.2	64.4	78.0	135.0	144.3	60.1	57.0	883.7	950.2	2536.7	192.3
Minimum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.5	9.5	6.9	0.0
Maximum	495.9	495.9	438.9	594.1	901.6	901.6	307.1	233.7	4781.7	4781.7	16078.8	1231.1

B.	February-March											
	E. superba				*T. macrura* (Adult and larval stages pooled)				*S. thompsoni*			
	1994	1994	1993	1992	1994	1994	1993	1992	1994	1994	1993	1992
Area	Survey D	Elephant I.	Elephant I.	Elephant I.	Survey D	Elephant I.	Elephant I.	Elephant I.	Survey D	Elephant I.	Elephant I.	Elephant I.
No. Tows	89	70	67	67	89	70	67		89	70	67	
Abundance: No./1000 m3												
Median	0.6	0.4	3.0	7.1	34.5	23.8	22.1		224.7	242.6	605.9	
Mean	18.6	17.1	35.0	38.0	118.9	77.1	128.9		523.5	495.1	1585.9	
Std. Dev.	69.6	63.5	89.7	77.4	228.1	132.6	235.1		704.7	579.4	2725.5	
Minimum	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	5.3	2.2	
Maximum	397.8	371.1	542.0	389.9	1481.9	815.9	1141.5		4185.0	2377.5	16662.5	

Table 4.5 IKMT tow information at X stations.

STATION #	DATE	START TIME	END TIME	DIEL	TOW DEPTH(m)	BOTTOM DEPTH(m)	VOLUME (m3)	KRILL:	TOTAL	#/M2	#/1000M3
BRANSFIELD STRAIT:											
X08	22/02/94	0810	0830	D	128	200	2158.2		2	0.12	0.93
X09	22/02/94	1006	1032	D	131	680	3633.7		11	0.40	3.03
X10	22/02/94	1229	1309	D	193	990	5541.4		0	0.00	0.00
X12	22/02/94	1701	1731	D	159	1683	3767.1		0	0.00	0.00
X13	22/02/94	1912	1945	D	128	1594	4728.9		2	0.05	0.42
X14	22/02/94	2115	2127	T	62	500	1420.5		3	0.13	2.11
								NO.	18		
								MEAN		0.12	1.08
								STD		0.14	1.13
TOTAL								MEDIAN		0.08	0.68
DRAKE PASSAGE NORTH OF KING GEORGE ISLAND:											
X15	23/02/94	0150	0212	N	109	185	2033.3		146	7.83	71.81
X16	23/02/94	0329	0404	N	100	400	1118.0		303	27.10	271.01
X17	23/02/94	0559	0628	D	109	1681	3901.4		519	14.50	133.03
X18	23/02/94	0858	0926	D	222	3000	1307.1		3	0.51	2.30
X19	23/02/94	1145	1213	D	184	2950	3590.7		6	0.31	1.67
X20	23/02/94	1458	1517	D	185	4000	2147.9		0	0.00	0.00
X21	23/02/94	1801	1824	D	136	5123	2925.7		0	0.00	0.00
								NO.	977		
								MEAN		7.18	68.55
								STD		9.60	95.18
TOTAL								MEDIAN		0.51	2.3
DRAKE PASSAGE NORTH OF ELEPHANT ISLAND:											
X22	24/02/94	0725	0755	D	144	3181	4881.2		4	0.12	0.82
X23	24/02/94	1027	1053	D	150	2442	4495.5		1	0.03	0.22
X24	24/02/94	1326	1352	D	128	1100	3462.7		2	0.07	0.58
X26	24/02/94	1722	1752	D	157	1488	4463.9		258	9.07	57.80
X27	24/02/94	1930	1955	T	210	981	3655.8		1	0.06	0.27
X28	24/02/94	2136	2204	N	232	584	3556.7		154	10.05	43.30
X29	24/02/94	2352	0008	N	85	140	2984.5		532	15.15	178.26
								NO.	952		
								MEAN		4.94	40.18
								STD		5.88	60.58
								MEDIAN		0.12	0.82
TOTAL								NO.	1947		
								MEAN		4.27	38.38
								STD		7.26	72.06
								MEDIAN		0.12	1.3

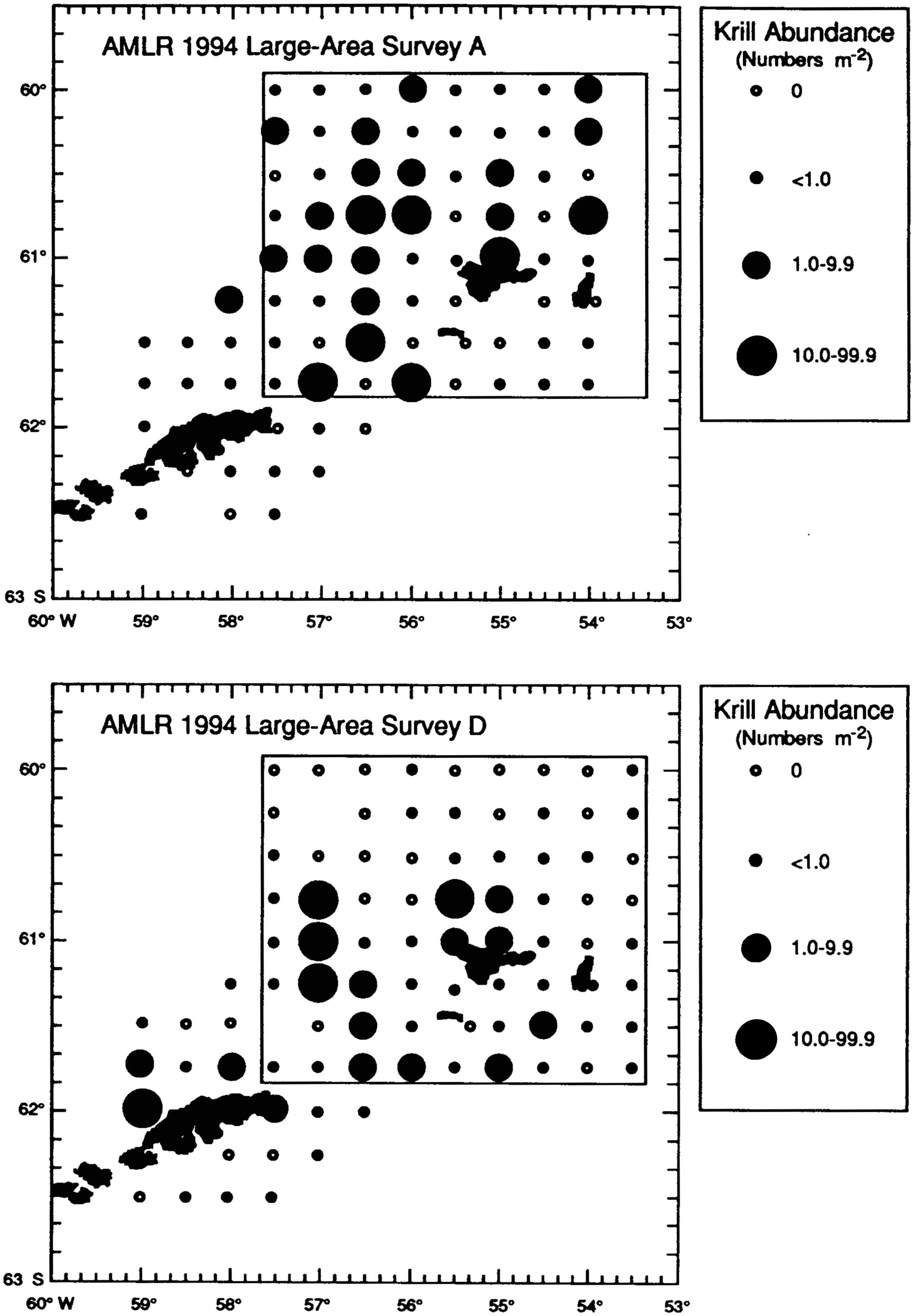


Figure 4.1 Krill abundance in IKMT tows collected during Survey A (17-28 January) and Survey D (25 February-9 March 1994). The outlined stations are included in the "Elephant Island Area" used for between-year comparisons.

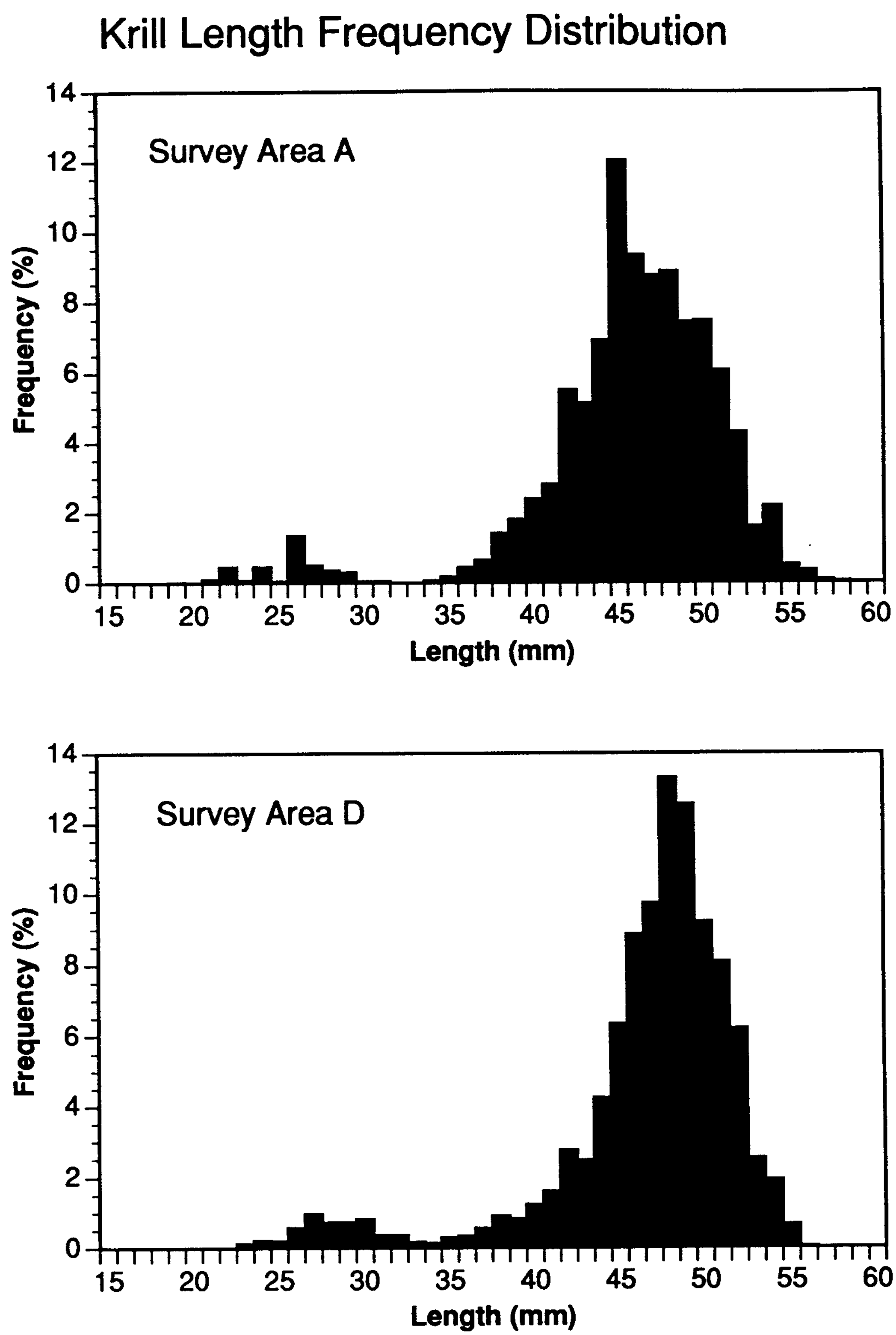


Figure 4.2 Overall length frequency distribution of krill collected during Surveys A and D.

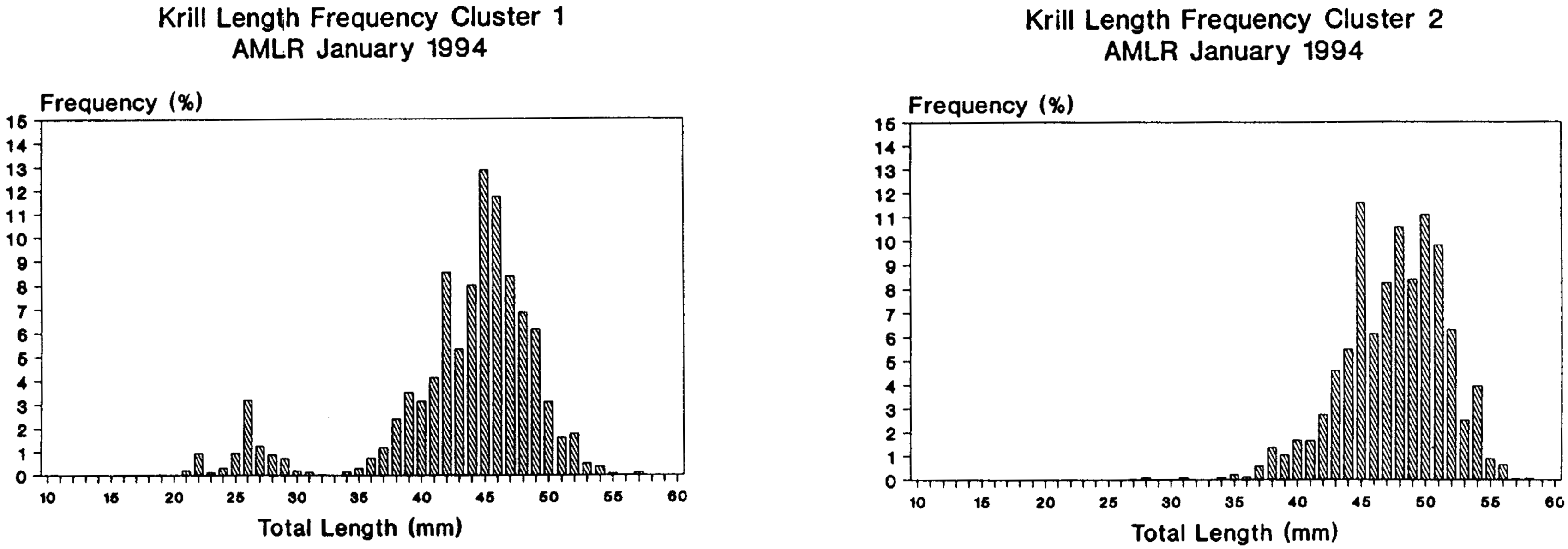


Figure 4.3 Length frequency distributions of krill belonging to two different length categories present in the Survey A area as determined by cluster analysis.

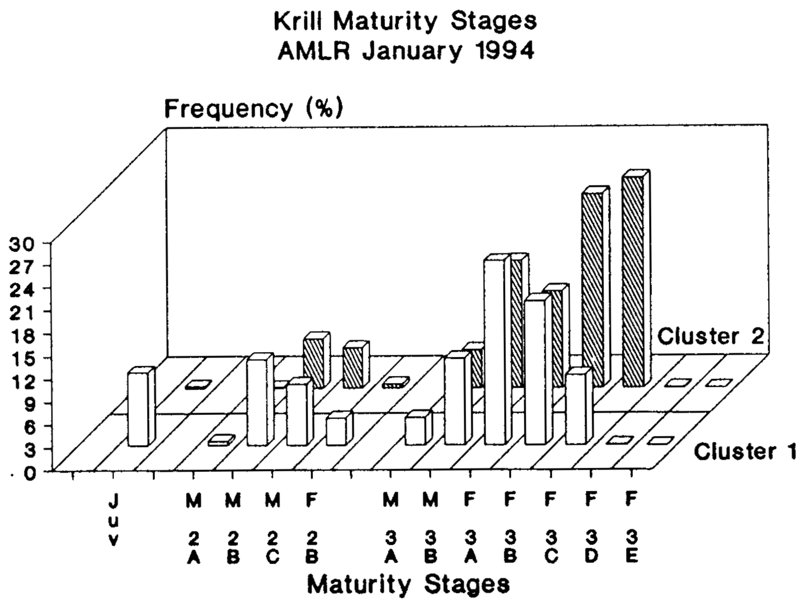
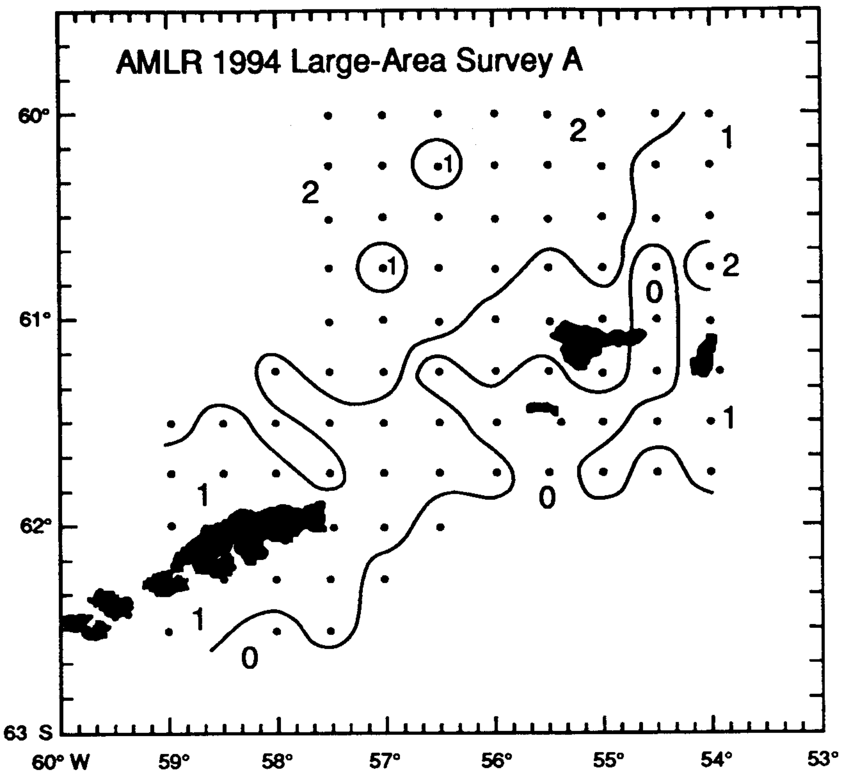


Figure 4.4 Maturity stage composition of krill associated with the two different length categories (Clusters 1 and 2) present in the Survey A area.



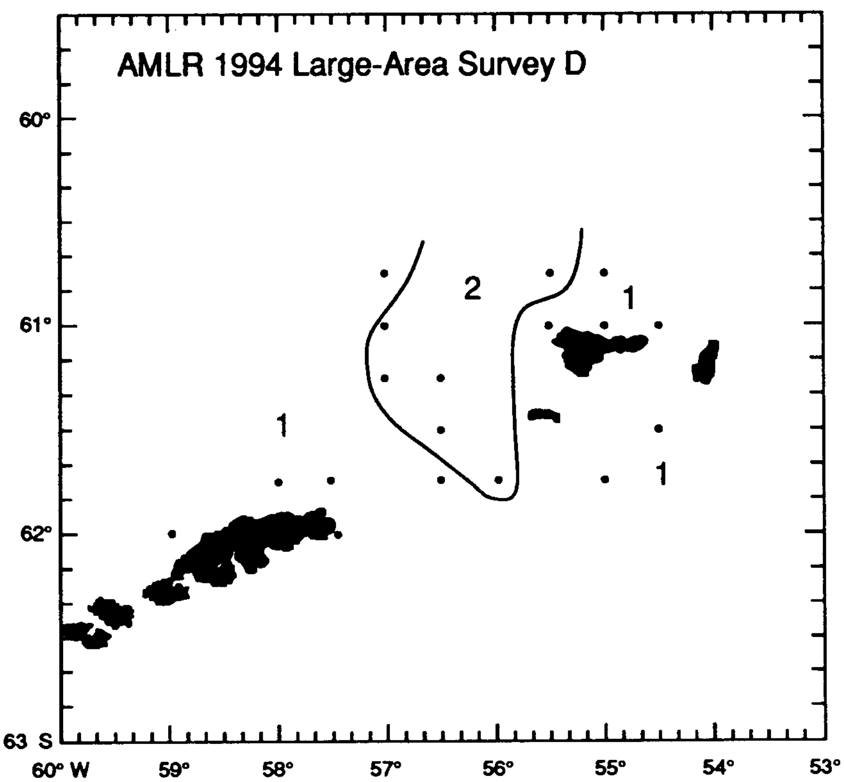


Figure 4.5 Distribution of krill belonging to two different length frequency categories (Clusters 1 and 2) in the Survey A and Survey D areas.

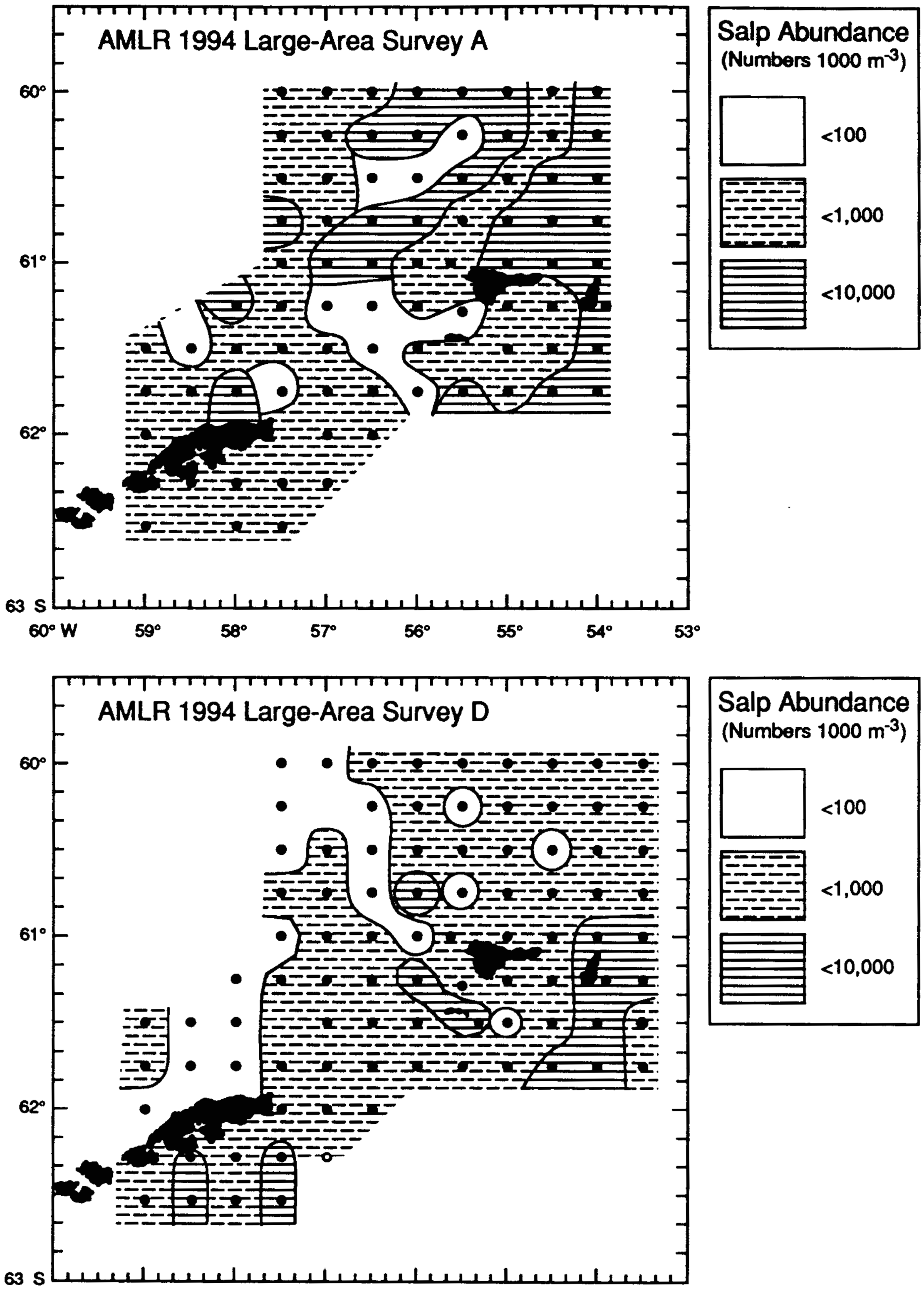


Figure 4.6 Distribution and abundance of salps (*Salpa thompsoni)* in the Survey A and Survey D areas.

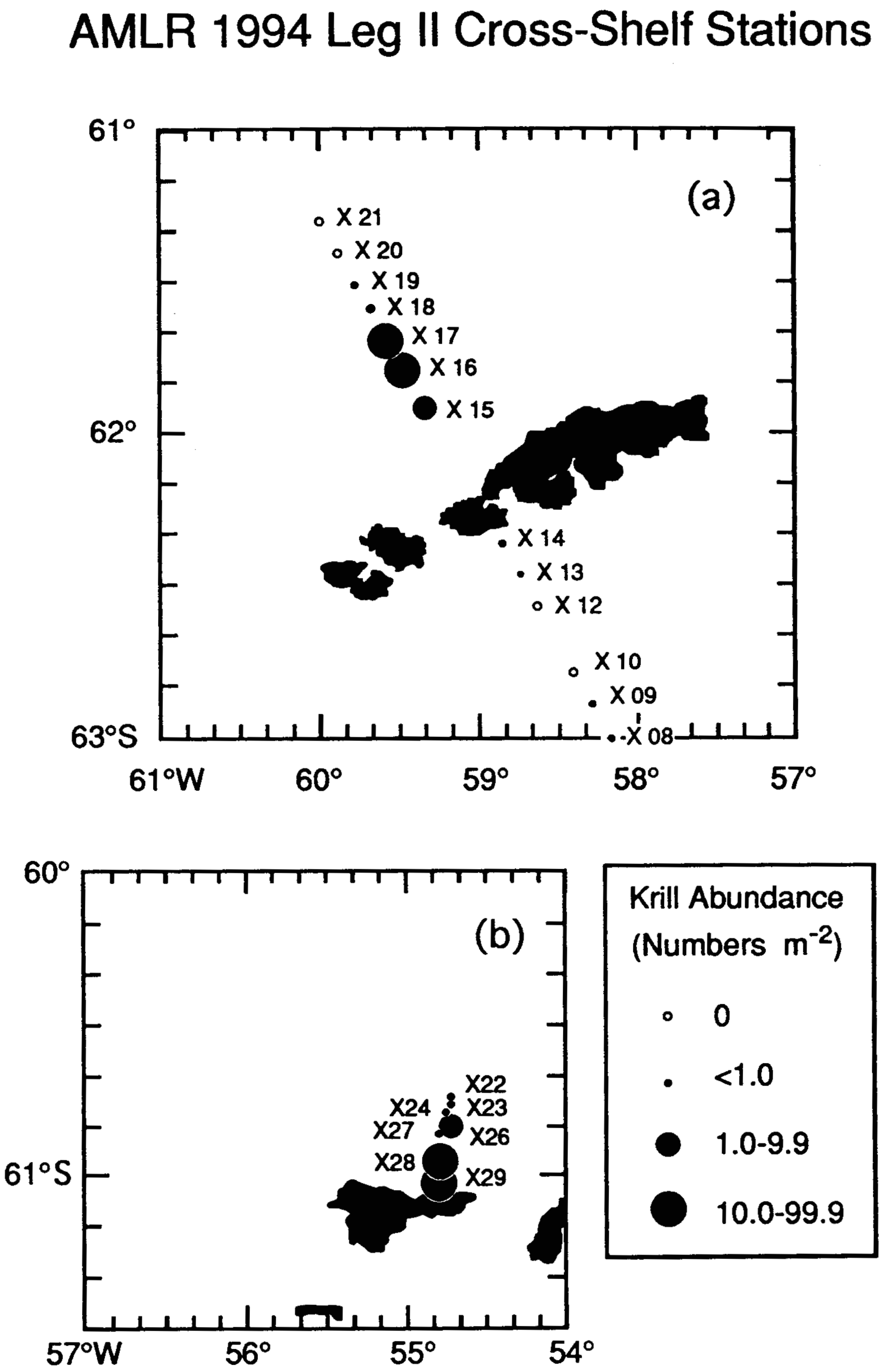


Figure 4.7 Krill abundance in IKMT tows conducted during Leg II's cross-shelf transects.

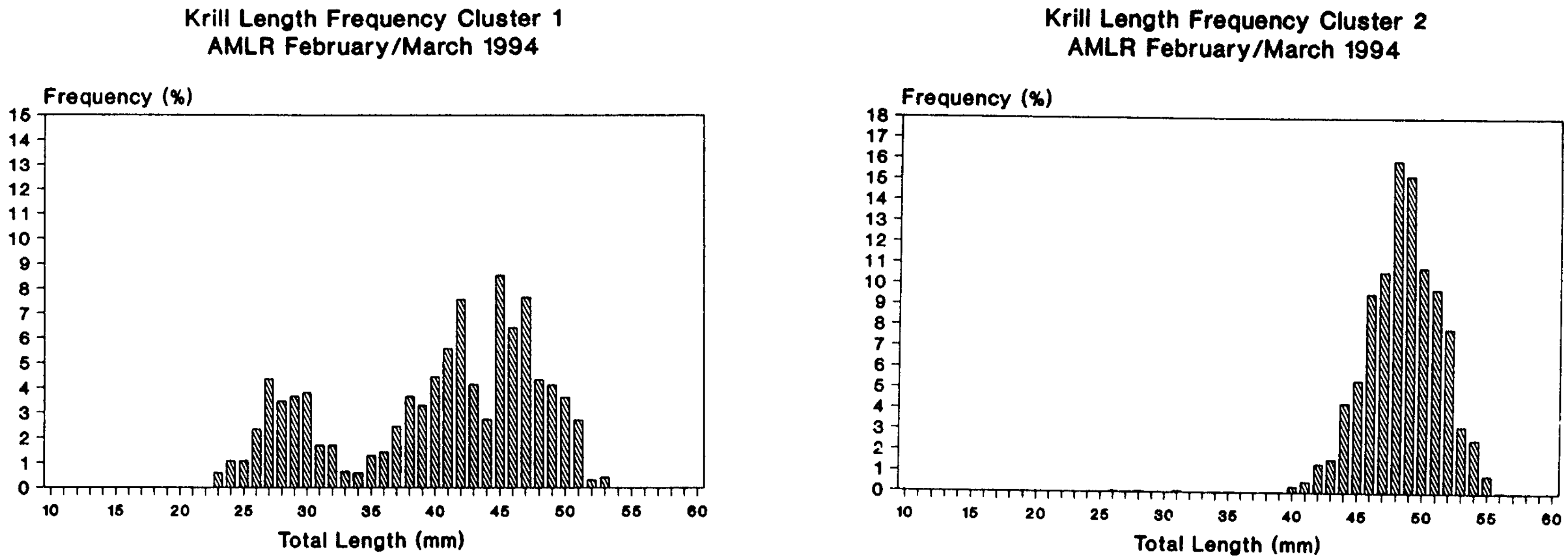


Figure 4.8 Length frequency distributions of krill belonging to two different length categories present in the Survey D area as determined by cluster analysis.

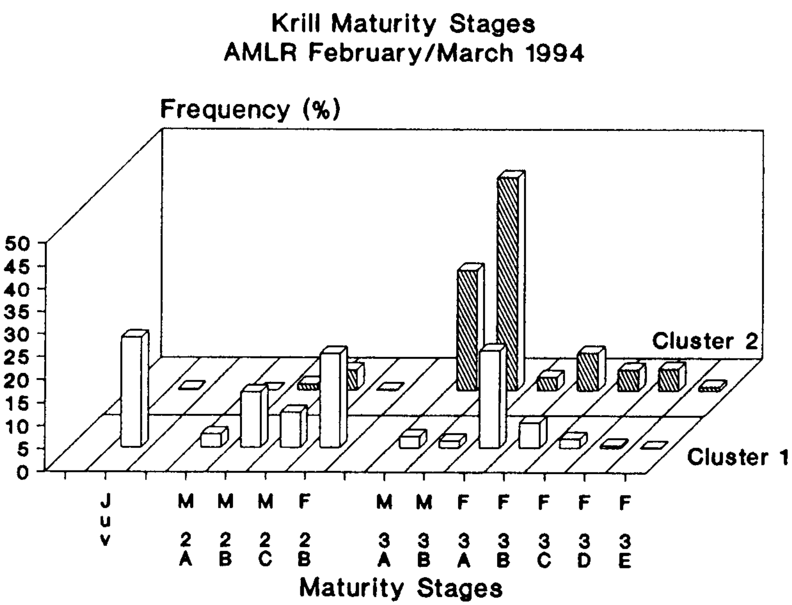


Figure 4.9 Maturity stage composition of krill associated with the two different length categories (Clusters 1 and 2) present in the Survey D area.

5. Seabird and marine mammal observations; submitted by G. Alan Reitsch (RITS, Legs I and II, Northbound Transit), Michael K. Schwartz (Leg I), and Jennifer L. Quan (Leg II).

5.1 Objectives: The objectives of the seabird and marine mammal observations were to: (1) determine a relative abundance and distribution of sea birds and marine mammals in the survey areas; (2) determine the correlation between Antarctic krill abundance/distribution and seabird and marine mammal abundance/distribution; and (3) collect identification photographs of humpback whales (*Megaptera novaeangliae*) which will be added to the Antarctic Humpback Whale Log housed at Allied Whale. Only seabird and marine mammal abundance are considered in this report. However, analysis of the potential relationship between marine predator abundance and krill abundance is presently underway.

5.2 Methods: Seabird and marine mammal observations were simultaneously conducted during the large- and small-area surveys. These operations took place on the flying bridge of the NOAA Ship *Surveyor*. Effort began daily at 0600 and ended at 1800. Watches were maintained by a single observer, entering seabird and marine mammal sightings into a time-event recording program on a laptop computer (TANDY 102). Environmental conditions (beaufort, sea state, swell, wind speed and direction, glare, and cloud cover) were also recorded to help define conditions affecting sighting ability.

During the large-area surveys, seabird observations were conducted only when the ship was transiting between CTD stations. Observations were continuous during the small-area survey, except when the ship stopped to deploy or remove the acoustic towed body. Therefore, the ship speed and observation effort were constant. Bird species, behavior, and number were recorded when birds passed through a visually defined 100 meter square area, situated 50 meters directly off the bow. Birds that followed the ship were counted only once on their initial pass through the square.

Bird observations were calculated for each species as birds per hour using the equation:

birds/hr = (# birds/minutes on each transect) * 60 minutes
where # birds = number of birds sighted on each transect

Marine mammal species, behavior, and number were recorded when animals were observed within a 180° arc forward of the ship. Additionally, a five-minute scan (using 8X magnification binoculars) was conducted every twenty minutes and covered an area out to four kilometers. These scans were continuous through transits and CTD stations.

Two additional data collecting systems were used to determine sighting positions and krill abundance: (1) A logging system (created by A. Amos) provided latitude, longitude, and time for the start of each five-minute marine mammal scan, marine mammal sighting, and the beginning and ending of observation effort. (2) The bioacoustics data (provided by R. Hewitt and D. Demer) included krill biomass and trackline positioning information. Trackline position and time were collected for every tenth of a nautical mile throughout both surveys. Bird positions were determined by combining bird sightings (collected with the time-event recording program) and the bioacoustics trackline positioning information matched to the closest minute.

Opportunistic photographs of baleen whales were taken in an effort to identify individuals. Unique pigmentation and scarring patterns on the underside of flukes, on the side, and on the dorsal fin will be used for identification. Various 300mm camera lenses and 200 ISO film were used to provide desired resolution of whales at a distance.

5.3 Results and Conclusions: During Leg I seabird and marine mammal observations were conducted a total of 95 hours and 45 minutes; 62 hours and 6 minutes of observation on the large-area survey (Survey A, 17 - 28 January) and 33 hours and 41 minutes on the small-area survey (Survey B, 29 January - 2 February). Observations were conducted on 43 of 91 transects during Survey A and 13 of 24 transects during Survey B. Observation time averaged 89 minutes for each large-area survey transect (range: 26 to 150 minutes), and 156 minutes on each small-area survey transect (range: 28 to 394 minutes).

A total of 72 hours and 23 minutes of observation were conducted during Leg II; 28 hours and 2 minutes during the small-area survey (Survey C, 17 - 19 February), and 44 hours and 21 minutes during the large-area survey (Survey D, 25 February - 9 March). Observations were conducted on 15 out of 24 transects during Survey C, and 33 out of 91 transects during Survey D. The average observation time for each small-area survey transect was 112 minutes (range: 22 to 254 minutes), and 80 minutes (range: 37 to 151 minutes) on each large-area survey transect.

A. Seabirds.

Table 5.1 lists the 27 species of seabirds observed during the large- and small-area surveys; common English and scientific names are provided.

Leg I, Survey A: During Leg I's large-area survey (Survey A), a total average of 27.38 birds were sighted per hour. The most abundant species in the survey area was Antarctic fulmars (*Fulmarus glacialoides*), which were sighted an average of 9.67 birds/hour. The second and third most abundant species were chinstrap penguins (*Pygoscelis antarctica*) and cape petrels (*Daption capense*), which were sighted an average of 5.23 and 3.75 birds/hour, respectively. The largest average number of birds observed per hour (181.82) was between Stations A49 and A50 (Figure 5.1). (Note: Thick solid lines on all figures indicate the observation transects.) The majority of these birds were Antarctic fulmars (sighted 156.36 birds/hour), but chinstrap penguins (16.36 birds/hour) and cape petrels (6.36 birds/hour) were also observed. The least number of birds observed per hour was between Stations A34 and A35, where no birds were sighted at all despite two hours and fifteen minutes of observation (Figure 5.1).

Leg I, Survey B: During the small-area survey (Survey B) of Leg I, the average number of birds sighted per hour was only slightly less than during the large-area survey: 26.28 birds/hour vs 27.38 birds/hour. Chinstrap penguins, sighted an average of 11.73 birds/hour, were the most abundant species during the survey, probably because of the survey's close proximity to known breeding colonies on Seal and Elephant Islands. Cape petrels were the second most abundant species, sighted 7.29 birds/hour. Antarctic fulmars, sighted 1.66 birds/hour, were much less abundant during this survey than Survey A. There are few, if any, breeding colonies for this species on the nearby islands, which may account for the lower abundance. The largest average number of birds sighted per hour (59.43) was between turn-points 12 and 13 (Figure 5.2). On this transect, 50.86 chinstrap penguins were sighted per hour. The least average number of birds observed per hour was between turn-points 18 and 19 (5.26 birds/hour) (Figure 5.2).

Leg II, Survey C: An average of 37.35 birds were sighted per hour during the small-area survey on Leg II (Survey C). Chinstrap penguins were the most abundant species during the survey (an average of 19.64 birds/hour), and again were probably associated with the nearby breeding colonies. Cape petrels and Wilson's storm petrels were the second and third most abundant species for the area (averages of 5.74 birds/hour and 3.62 birds/hour, respectively). The largest average number of birds per hour was observed between turn-points 8 and 9 (182.31), and the least was observed between turn-points 14 and 15 (1.94 birds/hour) (Figure 5.3).

Leg II, Survey D: A total average of 31.35 birds were sighted per hour during Leg II's large-area survey (Survey D). Cape petrels were the most abundant species (an average of 6.44 birds/hour). Antarctic fulmars were observed an almost identical amount (an average of 6.34 birds/hour), and chinstrap penguins were slightly less abundant (an average of 5.87 birds/hour). Black-bellied storm petrels (*Fragetta tropica*) were also fairly abundant during this survey (4.16 birds/hour, average). The largest average number of birds per hour (76.73) was observed between Stations D34 and D35 (Figure 5.4). The majority of these were Antarctic fulmars (sighted 57.12 birds/hour). The least average number of birds was observed between Stations D40 and D41 (3.00 birds/hour) (Figure 5.4).

B. Marine Mammals.

Table 5.2 lists the common English and Scientific names of the marine mammals sighted during the four surveys. It also gives the names of species that were sighted in the region while not conducting transect observations. (e.g., Arnoux's beaked whale and Weddell seals).

Leg I, Survey A: During Leg I's large-area survey (Survey A), minke whales (*Balaenoptera acutorostrata*) were the cetacean most often sighted (13 sightings), followed by similar but unidentified small cetaceans (6 sightings). Four fin whales (*Balaenoptera physalus*), five sei whales (*Balaenoptera borealis*), four southern bottlenose whales (*Hyperoodon planifrons*), and a total of eight unidentified large and medium whales were also sighted. Antarctic fur seals (*Arctocephalus gazella*) were sighted fifteen times and were more common than any other pinniped. During observation transects, only two other pinniped species were sighted: leopard seals (*Hydrurga leptonyx*) and an unidentified pinniped.

Leg I, Survey B: Hourglass dolphins (*Lagenorhynchus cruciger*) were the most common cetacean seen (5 sightings) during Leg I's small-area survey (Survey B). Minke whales (four sightings), southern bottlenose whales (two sightings), and two small unidentified whales were also observed during observation transects. Antarctic fur seals were the only pinnipeds sighted (four individuals) during the survey. However, many chinstrap penguin carcasses were observed, which may have been a result of leopard seal predation.

Leg II, Survey C: Long-finned pilot whales (*Globicephala melaena*) were the most abundant species during Leg II's small-area survey (Survey C) (55 to 65 animals). These animals were all seen in one group sighting. Hourglass dolphins were the next most abundant species with 22 animals sighted. Humpback whales were commonly sighted (15 animals). Also, 13 fin whales and 12 southern bottlenose whales were observed. Twenty-three Antarctic fur seals and 3 unidentified pinnipeds were observed during Survey C. The high Antarctic fur seal concentration was likely due to the breeding colonies on nearby Seal Island.

Leg II, Survey D: Long-finned pilot whales were the most abundant cetacean (40 to 50 animals) during the large-area survey (Survey D) of Leg II. As in Survey C, these animals were observed in one group sighting. In contrast, there were many sightings of fin whales, which totaled 27 animals. Hourglass dolphins were abundant (14 animals). Orcas (*Orcinus orca*) were sighted only during this survey (12 animals). For pinnipeds, only seven Antarctic fur seals were sighted during the survey.

C. Humpback Identification.

Individual identification photographs were taken of five to eleven humpback whales on a total of three occasions. These fluke or tail photographs will be compared to other photographically identified individuals cataloged at Allied Whale, College of the Atlantic. Resightings will help determine life histories, regional movement patterns, migration patterns, and population levels.

5.4 Disposition of Data: Tables listing the number of birds observed per hour for each observation transect of the large- and small-area surveys for each species (see Table 5.1) are available from Alan Reitsch, College of the Atlantic, Allied Whale, Bar Harbor, Maine 04609.

5.5 Problems and Further Analysis: Observations were influenced by various conditions, the most important of which was light conditions. Darkness did not allow observations on many of the transects; thus, our results do not show abundance and distribution in many areas. Weather most influenced our ability to detect animals; high winds, swell, fog, and glare made bird and mammal observations difficult. These observational conditions were recorded and can be factored into seabird and marine mammal population estimates.

In future research, a link between the ship's GPS system and the laptop computer would be very useful. Such a link would provide an immediate position for each sighting, and thus less post-processing of data would be necessary.

5.6 Acknowledgments: We would like to thank Dr. Richard R. Veit for his project contribution of a TANDY laptop computer. Without it, bird observations would have been much more labor intensive. Anthony Amos, Andrea Wickham, and Charles Rowe also deserve thanks for allowing us to log information on their system and for their assistance in extracting our data from their database. Thanks also to all the watchstander crew who helped spot an occasional marine mammal and pass the time up on the flying bridge, and to the junior officers on the bridge for their reports of marine mammals. Special thanks to CAPT Thomas Ruszala, Chief Scientists Drs. Rennie Holt and Roger Hewitt, and Field Operations Officer, Lt. John Lowell, for their support of photographic identification of baleen whales.

Table 5.1 Common English and scientific names of birds observed during the large- and small-area surveys.

English Name	Scientific Name
Wilson's Storm Petrel	Oceanites oceanicus
Black-bellied Storm Petrel	Fragetta tropica
Antarctic Tern	Sterna vittata
Unidentified Tern	(Sterna vittata or S. paradisaea)
Antarctic Fulmar	Fulmarus glacialoides
Cape or Pintado Petrel	Daption capense
Kerguelen Petrel	Pterodroma brevirostris
Soft-plummaged Petrel	Pterodroma mollis
White-chinned Petrel	Procellaria aequinoctialis
Unidentified Giant Petrel	(Macronectes halli or M. giganteus)
Southern Giant Petrel	Macronectes giganteus
Northern Giant Petrel	Macronectes halli
Unidentified Prion	(Pachyptila vittata or P. belcheri)
Broad-billed Prion	Pachyptila vittata
Blue Petrel	Halobaena caerulea
Black-browed Albatross	Diomedea melanophris
Light-mantled Sooty Albatross	Phoebetria palpebrata
Wandering Albatross	Diomedea exulans
Grey-headed Albatross	Diomedea chrysostoma
Gentoo Penguin	Pygoscelis papua
Chinstrap Penguin	Pygoscelis antarctica
Unidentified Penguin	(Many Species Possible)
Adelie Penguin	Pygoscelis adeliae
Unidentified Skua	(Catharacta maccormicki or C. antarctica)
South Polar Skua	Catharacta maccormicki
Brown or Antacrtic Skua	Catharacta antarctica
American Sheathbill	Chionis alba

Table 5.2 Common English and scientific names of marine mammals observed during the large- and small-area surveys.

English Name	Scientific Name
Humpback Whale	Megaptera novaeangliae
Fin Whale	Balaenoptera physalus
Sei Whale	Balaenoptera borealis
Minke Whale	Balaenoptera acutorostrata
Orca or Killer Whale	Orcinus orca
Southern Bottlenose Whale	Hyperoodon planifrons
Long-finned Pilot Whale	Globicephala melaena
Hourglass Dolphin	Lagenorhynchus cruciger
Unidentified Large Whale	(B. physalus, B. borealis, or M. novaeangliae)
Unidentified Medium Whale	(B. borealis, B. acutorostrata, H. planifrons, or Berardius arnuxii)
Unidentified Small Whale	(B. acutorostrata, H. planifrons, or B. arnuxii)
Leopard Seal	Hydrurga leptonyx
Antarctic Fur Seal	Arctocephalus gazella
Southern Elephant Seal	Mirounga leonina
Crabeater Seal	Lobodon carcinophagus
Weddell Seal	Leptonychotes weddelli
Unidentified Pinniped	(H. leptonyx, A. gazella, M. leonina, or Leptonychotes weddelli)

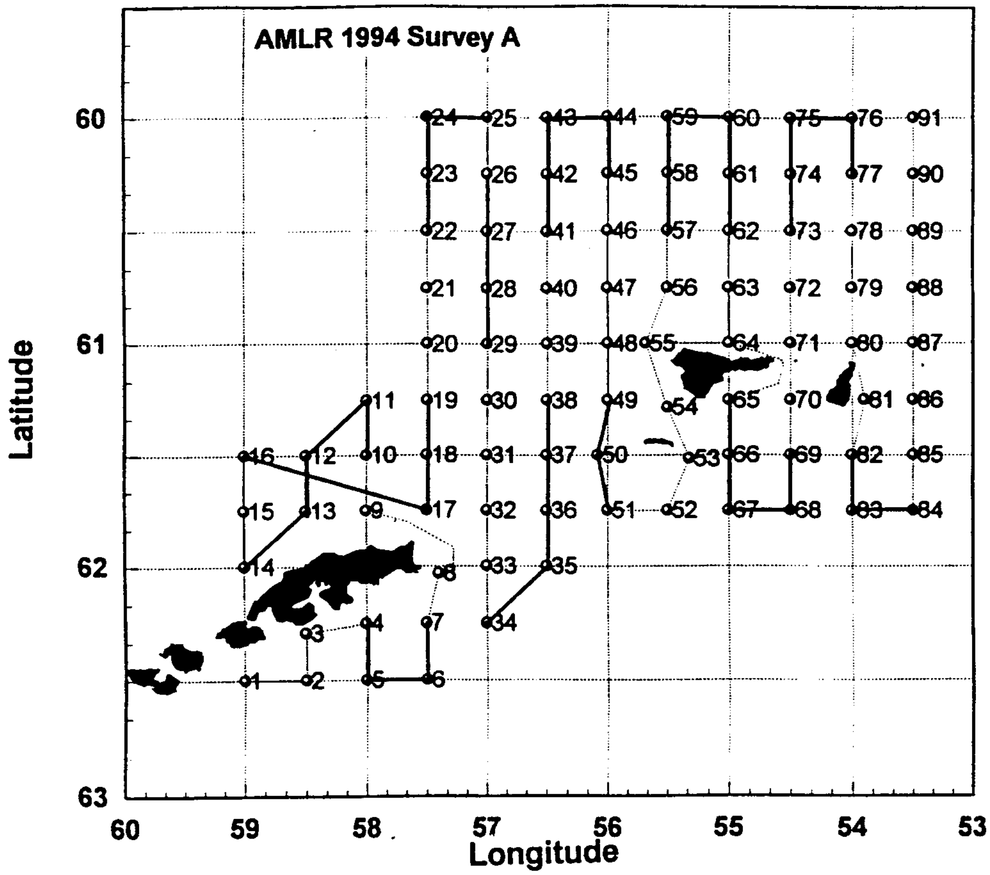


Figure 5.1 Observation of seabirds during Survey A. Thick solid lines indicate the observation transects.

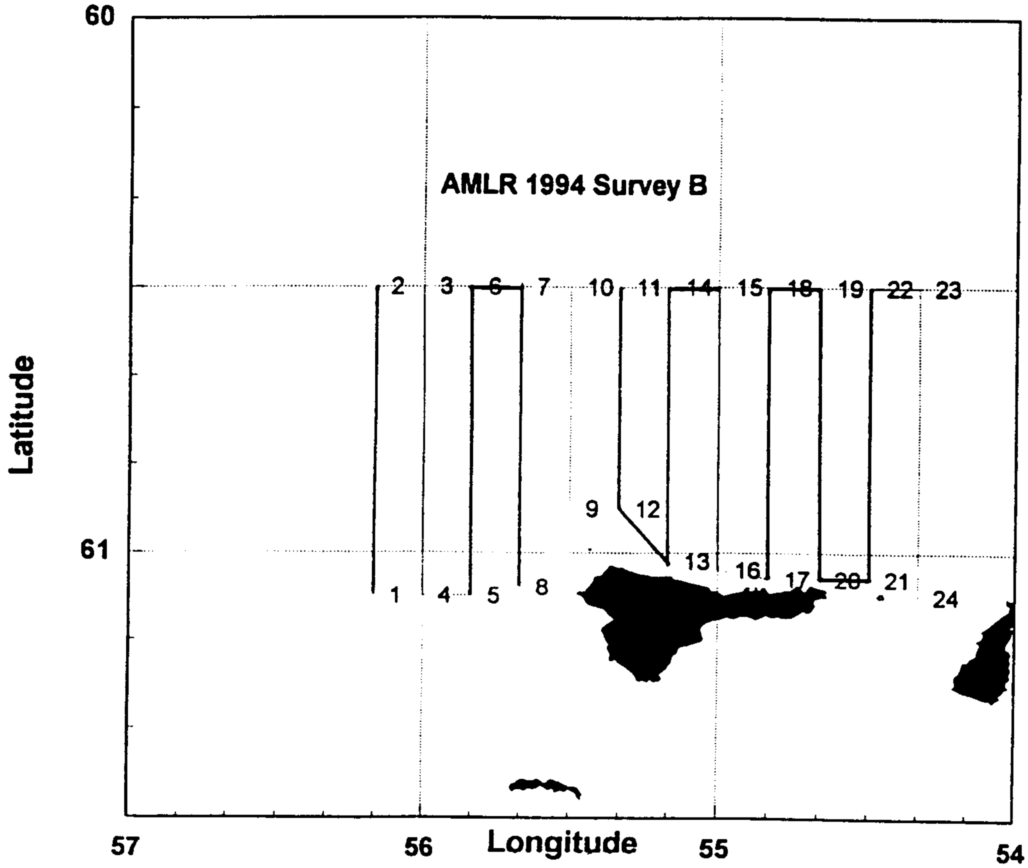


Figure 5.2 Observation of seabirds during Survey B. Thick solid lines indicate the observation transects.

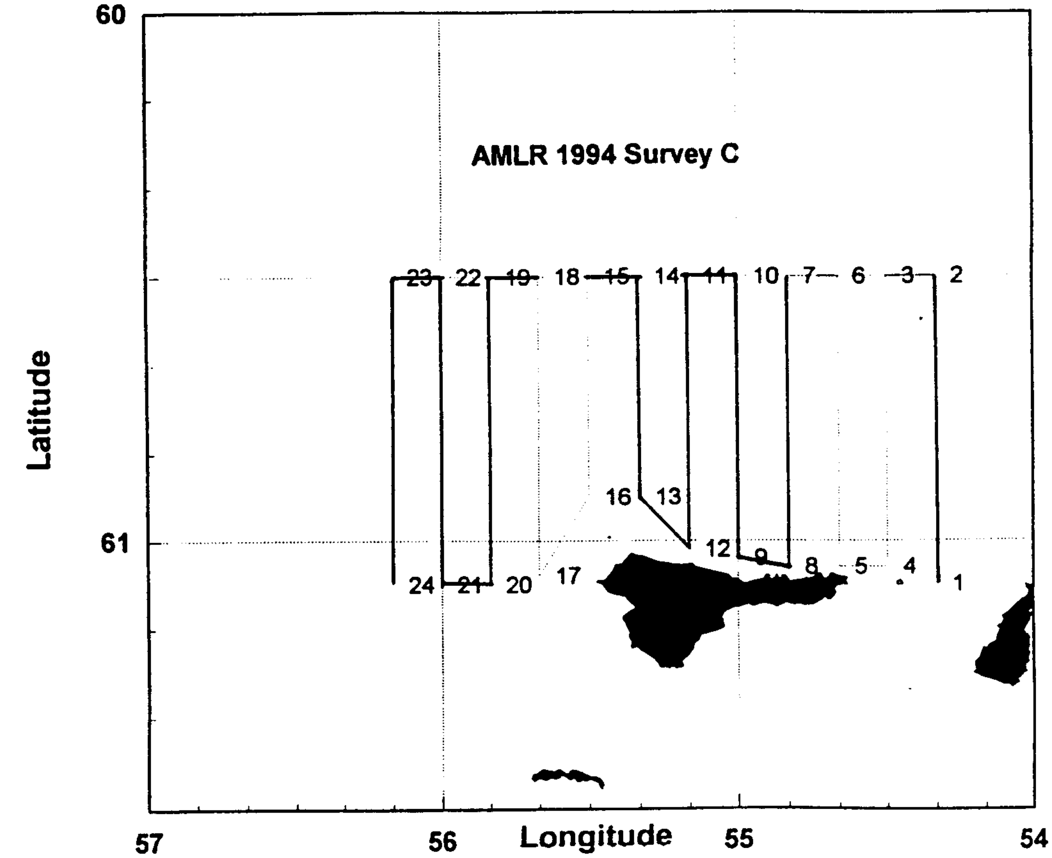


Figure 5.3 Observation of seabirds during Survey C. Thick solid lines indicate the observation transects.

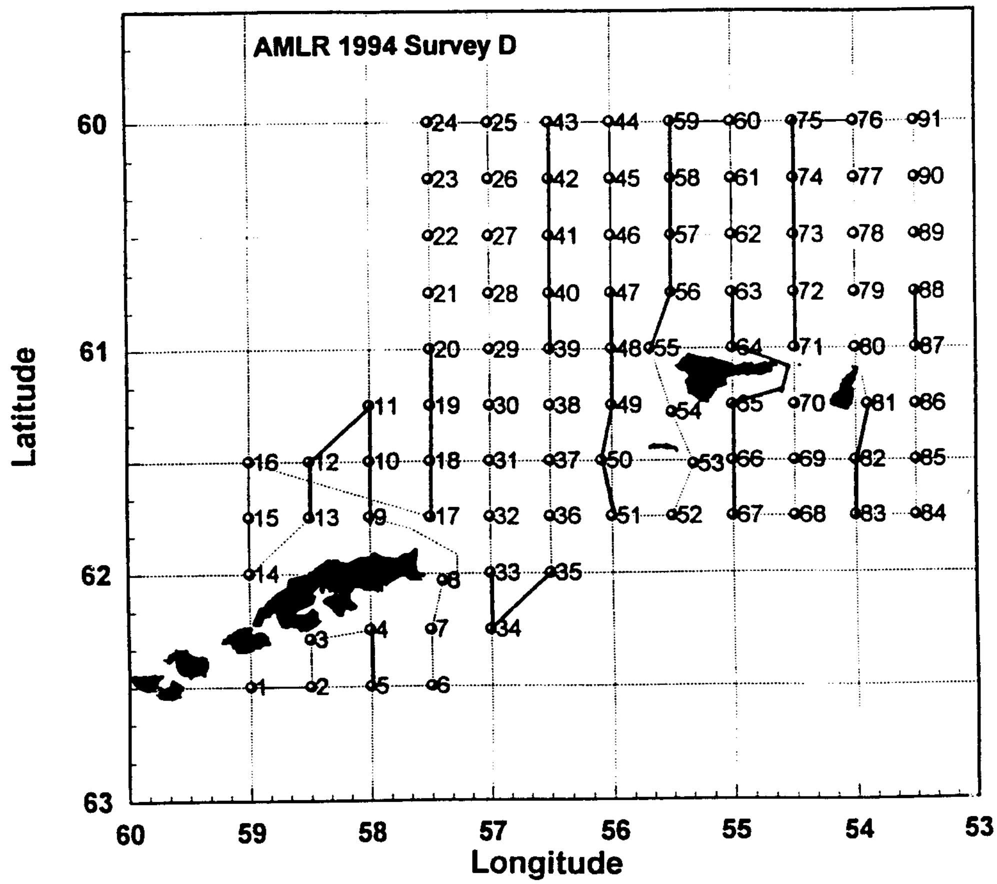


Figure 5.4 Observation of seabirds during Survey D. Thick solid lines indicate the observation transects.

6. Chlorinated hydrocarbons around the South Shetland Islands, Antarctica. Thermal structure of Drake Passage 1994; submitted by Christian Bonert Anwandter (Leg II).

6.1 Objectives: During Leg II of AMLR 94, two research projects were conducted by Chile's Servicio Hidrográfico y Oceanográfico de la Armada (SHOA). The objective of the first project was to detect the presence of various forms of chlorinated hydrocarbons in biological matrices around the South Shetland Islands.

The objective of the second project was to continue the expendable bathythermograph (XBT) observations started during the AMLR 1990 cruise for monitoring the thermal structure of the upper layers of the Drake Passage.

6.2 Accomplishments: Eight samples of biota were collected around Elephant and King George Islands. The content and identification of specific components of chlorinated matter will be analyzed by HPLC and gas chromatography with an electron capture detector at the SHOA laboratory in Valparaiso, Chile.

Seventeen XBT observations were conducted while crossing the Drake Passage at the beginning of Leg II (February 15-16) from about 35 n.mi. southeast of Tierra del Fuego (55°13'S, 64°34'W) to about 44 n.mi. offshore of Elephant Island (60°31'S, 55°50'W).

6.3 Tentative Conclusions: A preliminary description of the thermal structure spanning the Drake Passage is presented in Figure 6.1. In this transect, the Polar front (PF) is located between 58°24'S (59°33'W) and 58°49'S (58°55'W). As in past AMLR cruises, a cold water core with temperatures between -0.5 and -1.0°C was found south of the PF at a depth of 80 to 100m. This layer forms as a result of summer time solar heating of the upper portion of the deep, cold layer of winter surface water. It represents the remnants of the lower portion of the cold layer produced during winter time.

A cold water core with a ring configuration centered at a depth of 150m was detected approximately 170 n.mi. north of the PF. A similar thermal structure was found January 17-18 during Leg I of the 1991 AMLR cruise.

6.4 Acknowledgments: The author wishes to thank the AMLR program and the officers and crew of the NOAA Ship *Surveyor* for making these studies possible. My gratitude is extended to Dr. Osmund Holm-Hansen and Samuel Hormazabal for their collaboration in the development of my tasks.

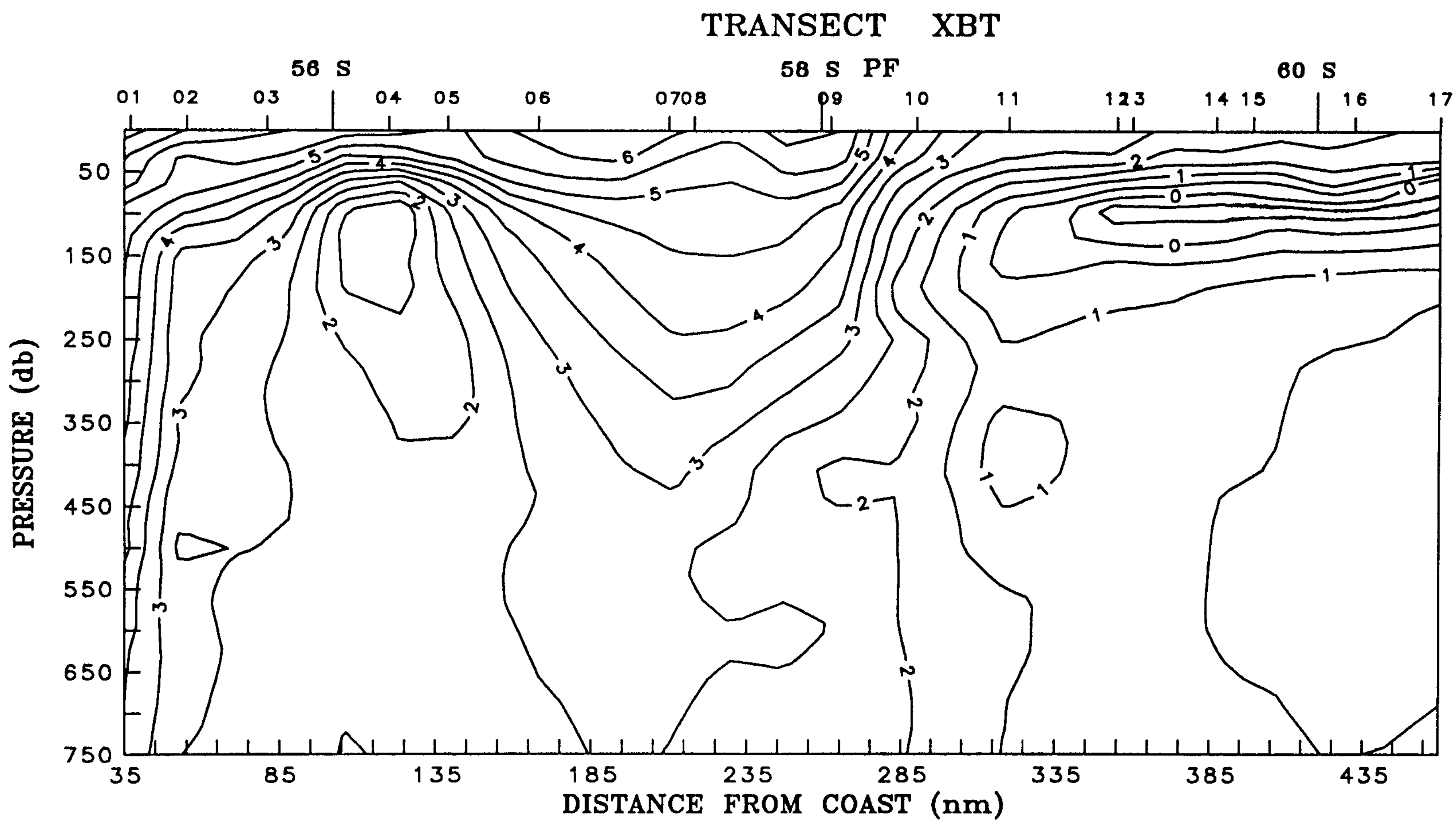


Figure 6.1 Thermal structure of the Drake Passage.

7. Operations and logistics at Seal Island, Antarctica, during 1993/94; submitted by P.L. Boveng and W.R. Meyer.

7.1 Objectives: The AMLR program maintains a field camp at Seal Island, South Shetland Islands, Antarctica (60°59'14"S, 55°23'04"W), in support of land-based research on marine mammals and birds. The camp is occupied during the austral summer field season, which normally runs from December through March. The main logistics objectives of the 1993/94 season were:

1. To deploy the field team early in December aboard the M/V *Explorer* in order to arrive at Seal Island in time to monitor fur seal pupping and penguin chick hatching,

2. To deploy one additional field team member to assist in field studies in mid-January and recover two field team members in early February aboard the NOAA Ship *Surveyor*,

3. To conduct a geologic/cartographic inspection of the island for use in safety analysis and construction of an accurate map of the island,

4. To resupply the field camp with its season's provisions, which were transported from the United States aboard the NOAA Ship *Surveyor*,

5. To maintain effective communications systems on the island and to maintain daily radio contact with either Palmer Station or the NOAA Ship *Surveyor*,

6. To repair, maintain, and improve camp facilities at the Seal Island field camp, and

7. To retrograde trash and other cargo from the island and to transport the field team to Chile at the end of the season aboard the NOAA Ship *Surveyor*.

7.2 Accomplishments: A five person field team departed the U.S. on 18 November 1993 and embarked the tour ship M/V *Explorer* in Stanley, Falkland Islands, on 21 November. After its trip south via South Georgia, the South Orkney Islands, and the South Shetland Islands, the ship arrived at Seal Island and disembarked the field team on 30 November. Good weather resulted in an efficient landing at the camp beach. Camp structures over-wintered well and without damage. The main tent, which serves as the principal accommodation, was erected within 2 days of the team's arrival.

The NOAA Ship *Surveyor* arrived and off-loaded cargo at Seal Island on 15 January. Cargo operations went smoothly with favorable weather conditions. As in past seasons, two Mark V Zodiacs were used to transport supplies ashore. The assistance of ship's personnel and members of the scientific party expedited cargo operations. In addition to the persons who came ashore to help unload and carry cargo up to camp, four swimmers in dry suits were stationed to steady the Zodiacs during unloading. Two researchers from Seal Island embarked

Surveyor to conduct a pinniped survey of the northern South Shetland Islands. The sixth member of the Seal Island field team and a US Army Corps of Engineers Geologist also came ashore during this visit.

On 4 February, *Surveyor* returned to Seal Island disembarking the two pinniped researchers, while two other members of the field team and the US Army Corps of Engineers Geologist embarked the ship for the return trip to Chile. *Surveyor* returned again to Seal Island on 17 February to off-load fresh supplies.

Daily radio communications were maintained with Palmer Station from 2 December to 14 January prior to the arrival of *Surveyor* in the operations area. Daily contact was maintained with *Surveyor* from 14 January to 10 March, using single side-band or VHF radio when the ship was within radio range of the island, or INMARSAT telephone (through the ATS-3 satellite) during the ship's port call between cruise legs. In addition to these regular schedules, radio contacts were made with biologists and other personnel at Palmer Station, Anvers Island (U.S.); Copacabana camp, King George Island (U.S.); King Sejong Station, King George Island (Korea); M/V *Explorer* (U.S.); and R/V *James Clark Ross* (U.K.). Communications were also maintained with various offices in the U.S. via the ATS-3 satellite system. No significant difficulties were experienced with any of the camp's communication systems.

Routine maintenance of camp facilities was undertaken as necessary. Obsolete and unneeded equipment was identified and removed from the island for shipment to the U.S. Wooden structures were painted and weatherproofed. As ice washed ashore only once during the entire season, a desalination unit was installed and operated to provide drinking water. The solar tracker array was augmented with the addition of two panels.

During the initial resupply of Seal Island on 15 January, trash from the early part of the season was transported to *Surveyor* for proper disposal. Additional trash and retrograde cargo was transported to *Surveyor* each time that the ship called at Seal Island to minimize the amount of cargo necessary to off-load at the end of the season. All remaining trash and cargo was loaded onto the ship on 10 March, when the camp was closed and the field team embarked the ship for transport to Chile.

7.3 Recommendations: Once again, the excellent support provided by the NOAA Ship *Surveyor* made a significant contribution to the success of the field season at Seal Island. Cargo and small boating operations went very smoothly. The practice of providing 4 swimmers in dry suits to assist landings and launchings of Zodiacs has proven to be very successful and should be continued in future seasons.

An arrival date in early December was ideal for initiating Antarctic fur seal studies prior to the peak of pupping. If possible, arrival of the field team should be planned for the first week of December in future seasons as well. Such an arrival date provides good access to female fur seals during their perinatal period, a requisite for the CCAMLR standard method for monitoring completion of foraging trip duration.

8. Pinniped research at Seal Island, Antarctica, during 1993/94; submitted by B.G. Walker, L.M. Hiruki, M.K. Schwartz, P.L. Boveng, and J.L. Bengtson.

8.1 Objectives: In 1993/94, pinniped research continued on Seal Island as part of the CCAMLR Ecosystem Monitoring Program (CEMP). This multi-national program is designed to detect significant changes in relationships between Southern Ocean top predators (such as pinnipeds), their principal prey species, and their environment. During the 1993/94 field season, specific objectives of the pinniped research at Seal Island were:

1. To monitor Antarctic fur seal pup growth rates and adult female foraging according to CEMP protocols,

2. To conduct directed research on fur seal pup production, female foraging behavior, diet, abundance, survival and recruitment,

3. To deploy and calibrate an automatic direction finding (ADF) system for determining the offshore foraging areas of fur seals,

4. To conduct directed research on the predator-prey relationship between leopard seals and fur seals, and

5. To monitor the abundance of all other pinniped species ashore.

8.2 Accomplishments:

Pup Growth Rates: Antarctic fur seal pups were weighed at two-week intervals from 30 December 1993 to 25 February 1994 (CEMP Standard Method C.2; Table 8.1). The growth rate for male pups was 132.7g per day (SE=4.8), and for female pups was 102.4g per day (SE=5.2). Biweekly mean weights were not significantly different than weights in 1992/93, with the exception of the first biweekly period for females, where the mean weight in 1993/94 was significantly greater than in 1992/93.

Foraging Behavior and Attendance Ashore: Female fur seal attendance on Seal Island was monitored using radio transmitters (CEMP Standard Method C.1). VHF radio transmitters (30 ms pulse; 164-165 MHz frequency) were attached to the backs of forty perinatal fur seal females from 4 to 11 December. Data logging computers located at the North Cove breeding colony recorded attendance for each instrumented female. Thirty-nine of the 40 females instrumented on Seal Island this season successfully completed six foraging trips, the standard used by CEMP for calculation of foraging trip duration statistics. Mean duration of all foraging trips (Trips 1 through 6) was 103.13 hours (SD=35.89, N=234). Averages for individual trips are given in Table 8.2.

Twenty of the 40 females instrumented with radio transmitters were also fitted with Wildlife Computers time-depth recorders (TDRs). These instruments are used to record dive characteristics and other foraging parameters females exhibit while at sea. Nineteen of the 20 TDRs were successfully recovered between 21 January and 12 February. In addition, one female fur seal was instrumented on 5 January with a special TDR equipped to measure swimming velocity, a parameter that may be very informative about foraging effort. That TDR was successfully recovered on 29 January. All TDR records will be analyzed at the National Marine Mammal Laboratory. These data will contribute to an initiative by CEMP to develop standard monitoring parameters of predator foraging performance.

Pup Production: Fur seal pups, both live and dead, were counted daily at the North Cove and North Annex colonies to estimate the total number of births in the main breeding areas. The maximum number of live pups recorded at North Cove was 206 on 4 January, and the maximum number of live pups recorded at North Annex was 79 on 20 January. Including a count of 2 dead pups in North Cove prior to 4 January, pup production was estimated to be at least 287 seals for the two major breeding colonies on Seal Island.

In addition to the two breeding colonies at North Cove and North Annex, the small breeding colony (Big Booté) on the east side of the island was censused periodically to estimate pup production. On 27 December, the maximum pup count of 12 was recorded in this colony.

A census of the fur seal colony on Large Leap Island, 1 km north of Seal Island, was conducted on 15 January. A total of 304 live pups (plus 2 dead pups) were counted in this colony.

Abundance, Survival and Recruitment: Because lactating female fur seals spend a large portion of time at sea during the breeding season and relatively few of the males in the population are present in the breeding colony, any census of the colony will fail to include an unknown, but substantial portion, of the population. The most reliable index of breeding population size, therefore, is the annual number of births which is nearly equal to the number of breeding females in the population. The total estimate of births (maximum live pup count plus numbers of dead pups observed) at North Cove, North Annex and Big Booté in 1993/94 was 299, similar to the total of 306 in 1992/93.

Leopard seal (*Hydrurga leptonyx*) predation on fur seal pups was directly observed on only three days this season, despite many observations of leopard seals in North Cove. Six pups were observed taken by one identifiable female leopard seal on three occasions (one on 3 February, two on 5 February, three on 6 February). This female was the only leopard seal observed hunting fur seal pups in 1993/94. Leopard seal predation appeared to occur later this season than in 1992/93, when predation was observed from late December to mid-January. Similar to previous seasons, pup numbers decreased significantly during periods when leopard seals were observed in the North Cove area.

All fur seals present on Seal Island were censused at weekly intervals along the accessible coastline from Beaker Bay to North Cove. Fur seals were classified into six groups: pups, females, adult males with females, adult males without females, subadult males, and juveniles of undetermined sex (Table 8.3). The total fur seal count increased until 16 February, with a maximum count of 1102 individuals in all size and sex classes. This number is lower than the maximum count for the 1992/93 season (3 March 1993; 1427 seals), but similar to the peak count for the 1991/92 season (18 February 1992; 1064 seals).

Daily observations of tagged female fur seals were made to assess female survival, reproductive rates, and tag loss. Of 90 tagged (but not instrumented) females observed during the 1992/93 season, 80 (88.9%) were observed again in the 1993/94 season. Sixty-four of these 80 females (80.0%) had pups in 1993/94. Of 43 tagged females instrumented with radio transmitters in 1992/93, 40 (93.0%) were observed again on Seal Island this season. Thirty-eight of these 40 (95.0%) had pups. During the field season, 19 new tags were placed on adult females of unknown age. This includes three females which were retagged with new All-Flex tags due to either the loss of one All-Flex tag previously administered (one case), or the replacement of smaller, more difficult to read Monel tags (two cases).

Antarctic fur seal pups have been tagged annually at both North Cove and North Annex since 1986/87. In the 1993/94 season, 90 known-age individuals, tagged in previous seasons, were observed on Seal Island (Table 8.4). A total of 198 pups (80 female, 113 male and 5 of unknown sex) were tagged with Monel flipper tags. Four subadult males and one adult male were seen with tags from other locations (Table 8.5).

Diet: Fur seal feces were collected during two-week periods, starting 28 December. Each sample consisted of three to ten scats collected from each sex. The samples were put in frozen storage for subsequent analysis of prey remains at NMML.

Offshore Foraging Areas: An ADF system for tracking the movements of radio-tagged fur seals and penguins was deployed at the top of Seal Island (elevation 130m). The ADF system uses four antennae oriented along the primary compass headings to detect signals from radio transmitters attached to the animals. The signal strengths received on each antenna are recorded automatically. The direction to an animal is obtained by resolving the vectors formed by the signal strengths on the four antennae. An approximate measure of distance can be obtained as a function of the total signal strength.

To assess precision of the angles provided by the ADF system and to determine the function relating signal strength to distance, a calibration test was conducted. This calibration test consisted of two parts:

1. Reference transmitters, similar to those carried by the animals but with batteries sufficient to transmit for five years, were placed on an islet 2 n.mi. to the WNW of Seal Island. The reference transmitters will provide long-term standard signals for detecting changes in gain caused by temperature and atmospheric fluctuations and for aligning ADF antennae in future seasons.

2. Transmitters (like those used on seals and penguins) were attached to a floating sled and towed along pre-determined tracklines by *Surveyor*. The angles and distances to the towed transmitters (estimated from the ADF system) will be compared with the "true" angles and distances, computed from the ship's GPS positions.

Preliminary analyses suggest that the ADF system is capable of estimating, with acceptable accuracy, the direction and distance to a seal or penguin foraging within about 11 n.mi. of Seal Island. Greater range may be achievable by future modifications to the power supply and/or by using more powerful transmitters. Data from the ADF study may assist discussions in CCAMLR of the overlap between krill fishing operations and foraging areas of krill predators.

Abundance of Other Pinniped Species: Counts of other pinniped species that use Seal Island as a haul-out location were done in conjunction with weekly counts of Antarctic fur seals. Southern elephant seals (*Mirounga leonina*), Weddell seals (*Leptonychotes weddelli*) and leopard seals were observed (Table 8.6).

Leopard seals were photographed and identified opportunistically. In the 1993/94 season, 60 sightings of leopard seals were recorded. At least 7 individual leopard seals were identified, including 3 subadults (2 males, 1 female).

Fur Seal Entanglements and Marine Debris: Five items of marine debris were found on Seal Island in 1993/94. Most were discarded shipboard items (i.e. packing bands, floats, styrofoam). One subadult male fur seal was observed entangled in man-made debris. The entangling material consisted of a loop of multi-fiber plastic packing band, encircling the upper neck area of the seal. The packing band was cut, but not removed from the animal, as it was embedded too deeply. A wound caused by the band encompassed at least half the circumference of the seal's neck.

8.3 Tentative conclusions: The 1993/94 season was typical with respect to pup production and growth indices, indicating that fur seal females were able to adequately obtain prey and feed their offspring. Although pup production was slightly lower than in 1992/93, survivorship appeared to be higher, perhaps due to later onset of leopard seal predation than in previous years.

Table 8.1 Mean weights, standard deviations, and sample sizes of male and female fur seal pups weighed during five sampling intervals, 30 December 1993 - 25 February 1994.

	Sampling Dates:				
	30 Dec.	13 Jan.	27 Jan.- 29 Jan.	10 Feb.- 11 Feb.	24 Feb.- 25 Feb.
MALE PUPS:					
Mean wt. (kg)	8.88	10.36	12.63	15.10	15.86
Std. dev.	1.37	1.44	1.45	1.52	2.14
N	61	57	62	56	58
FEMALE PUPS:					
Mean wt. (kg)	8.28	9.52	10.94	12.83	13.79
Std. dev.	1.35	1.22	1.64	1.49	1.65
N	39	43	33	41	39

Table 8.2 Mean duration of trips, standard deviation, sample size, maximum and minimum trip lengths for the first six trips to sea by 39 radio-transmitter-tagged lactating female fur seals breeding at North Cove, Seal Island, 1993/94.

Trip #	Mean duration (h)	Std. dev.	Maximum (h)	Minimum (h)	N
1	90.65	33.92	150.23	35.63	39
2	115.04	31.29	194.57	63.23	39
3	116.76	41.83	190.80	11.05	39
4	101.90	40.86	204.18	8.03	39
5	100.89	29.46	161.50	39.40	39
6	93.53	29.73	140.48	8.30	39
ALL	103.13	35.89	204.18	8.03	234

Table 8.3 Weekly counts of Antarctic fur seals, by sex and reproductive status, at Seal Island, Antarctica, 1993/94. These counts were made in a standard census area (which excludes the small fur seal rookery at Big Booté and other small haulout areas on the north-eastern side of the island).

Date	Pups	Adult females	Adult males with females	Adult males without females	Subadult males	Juveniles	Total
9 Dec	156	163	30	65	7	1	422
16 Dec	235	143	33	44	3	0	458
23 Dec	243	90	30	40	15	0	418
29 Dec	274	92	25	33	23	3	450
5 Jan	273	104	18	23	56	0	474
12 Jan	266	116	12	9	71	0	474
21 Jan	275	252	21	6	220	3	777
26 Jan	232	109	22	10	254	0	627
3 Feb	186	161	14	12	316	8	697
10 Feb	181	264	24	36	465	2	972
16 Feb	177	303	16	35	563	8	1102
23 Feb	178	219	25	60	518	5	1005
2 Mar	160	202	28	32	461	2	885

Table 8.4 Numbers of known-age fur seals observed on Seal Island, 1993/94.

Cohort	Males	Females	Total
1986/87	1	2	3
1987/88	9	3	12
1988/89	5	7	12
1989/90	1	0	1
1990/91	7	6	13
1991/92	20	11	31
1992/93	9	9	18

Table 8.5 Antarctic fur seals sighted at Seal Island with tags from other research locations, 1993/94.

Date	Size	Sex	Left/ Right	Number	Color	Tag type	Comments
26 Jan	Subadult	M	R	2618	White	small Rototag	Tag hole right flipper
11 Feb	Adult	M	L & R	L: 2928 R: 2929	White	large Rototag	
14 Feb	Subadult	M	L & R	L: 1536	Dark blue	Rototag	
20 Feb	Subadult	M	L	--	Aqua blue	Plastic	Tag hole right flipper
22 Feb	Subadult	M	R	1181	Orange	Rototag	Tag scar right flipper

Table 8.6 Weekly counts of pinnipeds other than Antarctic fur seals at Seal Island, Antarctica, 1993/94 (these counts reflect those seals hauled out at the specific time of the day's census).

Date	Elephant Seals	Weddell Seals	Leopard Seals
9 Dec	65	1	0
16 Dec	66	10	0
23 Dec	42	6	0
29 Dec	40	4	0
5 Jan	16	3	0
12 Jan	28	3	0
21 Jan	26	2	0
26 Jan	17	2	0
3 Feb	24	3	1
10 Feb	9	2	0
16 Feb	7	4	0
23 Feb	7	4	0
2 Mar	2	3	0

9. Seabird research at Seal Island, Antarctica, during 1993/94; submitted by J.K. Jansen, W.R. Meyer, M.K. Schwartz, and J.L. Bengtson.

9.1 Objectives: Studies on the life history of seabirds have provided valuable information about marine environments adjacent to breeding colonies. By examining aspects of seabird reproductive and foraging behavior, much can be learned about features of the local marine habitat. Several species of seabirds breed on Seal Island, including chinstrap penguins (*Pygoscelis antarctica*), macaroni penguins (*Eudyptes chrysolophus*), cape petrels (*Daption capensis*), Wilson's storm petrels (*Oceanites oceanicus*), and kelp gulls (*Larus dominicanus*). Southern giant petrels (*Macronectes giganteus*) and blue-eyed shags (*Phalacrocorax albiventer*) breed on adjacent islands. The seabird research at Seal Island focuses on chinstrap and macaroni penguins, with pilot studies currently being conducted on cape petrels. This work is being conducted as part of the CCAMLR Ecosystem Monitoring Program (CEMP), for which comparable studies are being undertaken at various sites in Antarctica. The principal research objectives for the 1993/94 field season were:

1. To monitor the breeding success, fledging weight, reproductive chronology, foraging behavior, diet, abundance, survival, and recruitment of chinstrap and macaroni penguins according to CEMP protocols,

2. To examine penguin chick growth and condition for intra- and inter-seasonal comparisons,

3. To conduct directed research on seasonal and diel patterns in the diving behavior of chinstrap penguins,

4. To assess the reproductive success, breeding chronology, survival, and recruitment of cape petrels, and

5. To continue testing an automatic direction finding (ADF) system for monitoring the locations of offshore foraging areas of chinstrap penguins.

9.2 Accomplishments:

Reproductive Success and Chronology: Breeding success was estimated according to CEMP Standard Methods A.6.B. (observations of two plots, minimum 100 nests per plot) and A.6.C. (discrete counts of ten CEMP colonies). Method A.6.B. is designed to determine the number of chicks raised to the creche stage. Rectangular plots were marked by stakes in 2 colonies and individual chinstrap penguin nests were identified (120 and 125 nests in the Parking Lot (PL) and North Cove (NC) study plots, respectively). Thirty macaroni penguin nests at Mac Top colony were also monitored. These nests were observed every other day from an observation blind, and the number of incubated eggs and/or brooded chicks was recorded. Overall, the number of chicks produced from chinstrap penguin nests active at the commencement of observations (7 December for both PL and NC plots) was 1.41 and 1.35

chick/active nest for PL and NC colonies, respectively. Table 9.1 presents selected indices of breeding success for all years since 1989/90. A comparison of inter-annual chinstrap penguin breeding success since 1989/90 is provided in Figure 9.1.

The PL and NC nest plots were also used to determine the chronology of penguin reproductive events at Seal Island through creching (Table 9.2). Upon completion of creching, the number of chinstrap penguin chicks was counted every day in Colony 66 (a colony of approximately 300 nests) to provide an estimate of the chronology of fledging (Table 9.2).

According to CEMP Standard Method A.6.C., three censuses were made of 10 geographically discrete chinstrap penguin colonies undisturbed by other activities (Colonies 9, 21, 24, 31, 32, 33, 42, 51, 54, and 66) at completion of laying, completion of hatching, and completion of creching. During the incubation and creche phase censuses, three replicate counts were made of each colony on the same day. If one of the three counts differed by more than 10% of any other count, a fourth count was made. Each of the five macaroni penguin colonies was also censused. Data from the past five seasons of chinstrap and macaroni penguin censuses are summarized in Figures 9.2 and 9.3.

Foraging Behavior: The duration of adults' foraging trips to sea was monitored to determine the amount of time required to meet their own energetic needs and procure food for chicks, serving as an indicator of foraging effort and prey availability (CEMP Standard Method A.5.). Forty adult chinstrap penguins were equipped with radio transmitters (one bird each at 40 nests). An automatic scanning radio receiver and data logger recorded the attendance of radio-tagged birds every fifteen minutes. Nests of instrumented birds were checked regularly for survival of chicks and failed nests were excluded from subsequent analyses. Hatching dates for most of the study nests were recorded to allow better discrimination of the effects of chick growth and increasing energetic demands on adult foraging effort. Understanding this source of variability will increase our ability to detect potential inter-annual trends in foraging trip duration.

In order to provide detailed information on chinstrap penguin diving behavior at sea, 40 chinstrap penguins were equipped with time-depth recorders (TDRs): 10 during incubation, 10 during the early guard stage, 10 during the late guard stage, and 10 during the creche stage. Of these deployments, 38 records were obtained.

Diet: To examine the relationship between available food offshore and prey brought back to the colonies to provision offspring, 40 stomach lavage samples were collected from breeding chinstrap penguins between 8 January and 12 February 1994 (CEMP Standard Method A.8.). The sampling schedule was divided into eight 5-day collection periods. Adult birds were captured immediately upon returning to the colony after feeding trips to sea. These birds were weighed, measured (culmen length, culmen depth, and wing length), and banded prior to sampling. Stomach samples were obtained by a water off-loading technique using warm water.

In order to investigate potential diel changes in foraging behavior and prey availability, diet samples were taken from birds both returning from night and early morning foraging trips as well as birds returning from daytime foraging trips. As in previous years, Antarctic krill (*Euphausia superba*) was again the most abundant prey species found in all birds sampled; birds feeding nocturnally were more likely to have remains of fish in their stomachs. Seventy-five percent of all samples (n=20) taken from nocturnal/early morning foragers revealed evidence of fish. In contrast, only 5% of the samples (n=20) taken from diurnal foragers contained evidence of fish. Samples were sorted to remove otoliths and other prey hard parts in preparation for preservation and transport to NMML for further detailed analysis.

Abundance, Survival, and Recruitment: After the completion of egg laying, the number of breeding pairs of penguins in all colonies on the island was counted. The timing of this count, performed annually on 17 December, was determined by the field team's usual arrival date at Seal Island, which is after egg laying has begun. All birds lying down in some sort of nest structure were assumed to be occupying a nest site and were thus considered breeding. Large colonies (Colonies 3, 4, 14, 25, 26, 58, and 61) were counted from photographs. The total number of chinstrap penguin pairs nesting in 1993/94 will be determined pending the analysis of these photographs. A total of 299 pairs of macaroni penguins attempted to breed on Seal Island in 1993/94, 28 more than recorded the previous year.

Two-thousand chinstrap and 84 macaroni penguin chicks were banded to estimate annual survivorship and recruitment into the breeding population. By re-sighting banded birds in subsequent years, an estimate of age specific annual survival and recruitment can be calculated. Both systematic and opportunistic surveys to re-sight banded birds were conducted throughout the season.

Growth and Condition: To obtain another index through which to compare penguin performance between and within seasons, growth rates of chinstrap penguin chicks were monitored for the seventh consecutive year. Data on chick growth were collected by measuring the weight, culmen length, culmen depth, wing length, and noting the status of juvenile plumage molt every 5 days between 7 January and 21 February at Parking Lot colony. Prior to creching, no less than 50 chicks present in at least 30 nests were measured during 5 sampling periods. After creching, a total of 75 chicks were measured in each of three sampling periods. After handling, chicks were marked to avoid sampling them more than once during the season. Mean chinstrap penguin chick weight peaked at 3.37kg on 6 February.

Following the initiation of chinstrap penguin fledging on 11 February, daily samples of fledglings present at Beaker Bay were weighed (CEMP Standard Method A.7.A.) until the completion of fledging on about 3 March. A total of 303 fledglings were weighed and measured. Mean fledgling measurements were: weight, 2.98kg (SD=0.39); culmen length, 41.6mm (SD=3.1); culmen depth, 14.2mm (SD=1.1); and wing length, 108.8mm (SD=5.4). Fledging peaked on 18 February.

Macaroni chick weight, culmen length, culmen depth, and wing length were measured and the status of juvenile plumage molt was noted when banding chicks on 16 February. Morphometric data collected on these dates will provide a comparison of chick condition prior to fledging for all past years. Mean weights at this time were 3.26kg (SD=0.49), culmen length and depth were 43.86mm (SD=3.18) and 16.33mm (SD=1.48), respectively, while mean wing length was 105.39mm (SD=5.85).

Offshore Foraging Areas: An ADF system for tracking the movements of radio-tagged penguins and seals was deployed and calibrated. For details, see section on Pinniped Research on Seal Island in this volume.

Cape Petrels: The protocol for annually monitoring cape petrels was expanded this season. Prior to 1993/94, overall reproductive success of breeding cape petrels was estimated by conducting an initial census upon arrival at Seal Island and a census just prior to fledging (18 February). Counts had also been conducted at approximately two-week intervals throughout the season to monitor egg/chick mortality.

During the 1993/94 field season, twenty-three cape petrel nests at various locations were monitored to determine a breeding chronology on which to base subsequent census efforts. These nests were observed every other day during two phases (3-19 January and 22 February-8 March) to determine the initiation, peak, completion, and mean dates of hatching and fledging events. Hatching began on 11 January, peaked on 13 January, and was completed by 19 January. Fledging was initiated 26 February, peaked on 2 March, and was completed by 8 March. Mean dates of hatching and fledging were 15 January and 3 March, respectively.

Three censuses were conducted at four sites (65 nests) situated in different habitats: (1) two weeks prior to hatching, (2) completion of hatching, and (3) immediately prior to fledging. The status of each nest was recorded (empty, occupied but empty, incubated egg, attended chick, or unattended chick). Hatching success (the proportion of nests with eggs at the onset of observations that successfully hatched chicks) was 0.84. Fledging success (proportion of hatched chicks raised to fledging) was estimated at 0.86, and reproductive success (the proportion of nests with eggs at the beginning of observations that successfully fledged chicks) was estimated at 0.72. Chicks were banded on 22 February (forty days after the mean date of hatching) at which point weight, culmen length and depth, and wing chord measurements were taken on 45 chicks. Mean weight was 574g (SD=62g), mean culmen length was 30.2mm (SD=1.8mm), mean culmen depth was 8.4mm (SD=0.5mm), and mean wing chord was 213mm (SD=23mm). Material regurgitated by chicks during banding indicated that chicks were being fed primarily krill, although there was evidence of fish.

9.3 Preliminary conclusions: The 1993/94 season was more successful than the previous season with regard to foraging and provisioning of seabirds at Seal Island. The overall proportion of chinstrap penguin chicks raised to the creche stage from eggs present upon the field team's arrival was 69%, 2% higher than the 1992/93 season and the highest observed in all past years. This enhanced success (compared to the 1992/93 season) in rearing chinstrap penguin chicks may be attributed to both an increase in hatching success (77% vs 72%) and an increase in the proportion of nests raising two chicks to the creche stage (1.65 vs 1.60 chicks per nest). These successes may offset the reduction in the proportion of total hatched chicks raised to the creche stage (89% vs 92%) this season. As well, there was a slight decrease in both the number of chinstrap penguins attempting to breed (9% decline) and thus the total number of offspring hatched (9% decline) in the ten CEMP colonies during 1993/94.

Additionally, chinstrap penguin reproductive chronology at sample colonies was advanced. Peak fledging occurred earlier this season than in all previous seasons by 4-11 days. Mean weight of chinstrap fledglings was lower than all past seasons except for 1990/91, although the reasons for the lower weights are unclear.

The number of macaroni penguins breeding on Seal Island was 8% greater in 1993/94 than in 1992/93, and second only to the 1989/90 season (299 vs. 302 nests). Furthermore, the proportion of hatched macaroni chicks raised to creche increased 11% (91% vs. 80%). Cape petrels had a successful breeding season, with fledging chicks having a 6.3% higher mass (574g vs 540g) than the 1992/93 season.

Table 9.1 Indicators of chick rearing success for chinstrap penguins nesting at Seal Island, Antarctica, from 1989/90 through 1993/94. Values were calculated as averages from the Parking Lot (PL) and North Cove (NC) study plots.

Year	**1989/90**	**1990/91**	**1991/92**	**1992/93**	**1993/94**
Peak chick weight (kg)	3.40	3.30	3.41	3.35	3.37
Mean fledging weight (kg)	3.0	2.90	3.13	3.08	2.92
Chicks creched per initial active nest	1.20	1.35	1.40	1.25	1.35
Chicks per active nest (post-creche)	1.45	1.45	1.60	1.60	1.65
Chicks hatched (per eggs laid)	0.84	0.79	0.81	0.72	0.77
Chicks creched (per eggs hatched)	0.68 * (79/56)	0.73 **	0.84	0.92	0.89
Chicks creched (per eggs laid)	0.57 * (67/47)	0.61 **	0.68	0.67	0.69

* High waves at NC during chick rearing caused significant mortality within the study plot (values in parentheses indicate the PL and NC study plot values, respectively).

** NC colony disrupted by high waves -- only data from PL were available for this calculation.

Table 9.2 Nesting chronology of chinstrap and macaroni penguins at Parking Lot study plot and Colony 66 on Seal Island, 1993/94.

	Chinstrap penguins			Macaroni penguins
	Parking Lot	North Cove	Colony 66	Parking Lot
Start hatching	18 Dec	20 Dec	---	23 Dec
Peak hatching	23 Dec	29 Dec	---	26 Dec
Start creching	20 Jan	20 Jan	---	20 Jan
Peak creching	22 Jan	30 Jan	---	21 Jan
Start fledging	---	---	12 Feb	18 Feb
Peak fledging	---	---	18 Feb	---
Complete fledging	---	---	3 Mar	26 Feb

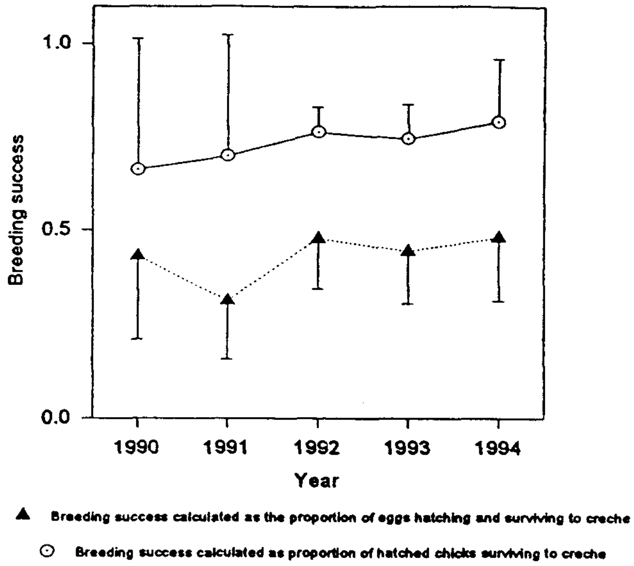


Figure 9.1 Inter-annual comparison of two mean estimates of chinstrap penguin breeding success on Seal Island, Antarctica, 1989/90 through 1993/94. Symbols indicate the mean estimates and one standard deviation at colonies censused for CEMP standard method A.6.C (n=10) representative of various habitat types on the island.

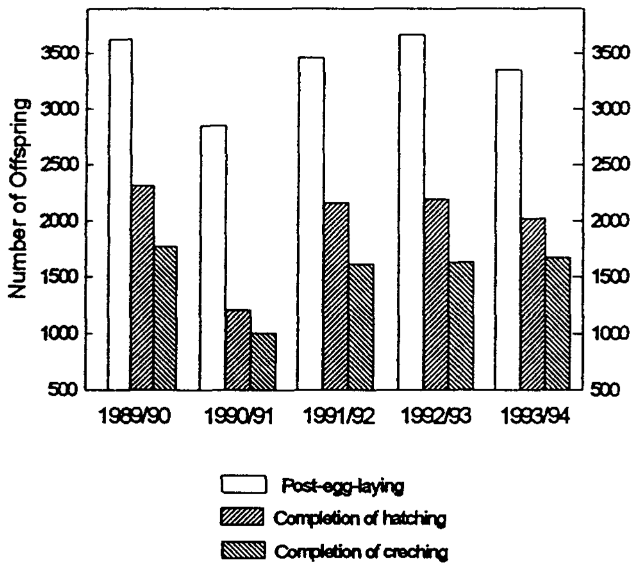


Figure 9.2 **Number of chinstrap penguin offspring surviving to various stages of development at ten colonies on Seal Island, 1989/90 through 1993/94. Data for post egg-laying were collected upon arrival at the field camp in December and therefore do not take into account early mortality that might have occurred between actual egg-laying and the census date. The post egg-laying censuses for 1989/90 and 1990/91 were conducted approximately ten days later than in the three following seasons, which would underestimate the initial breeding population.**

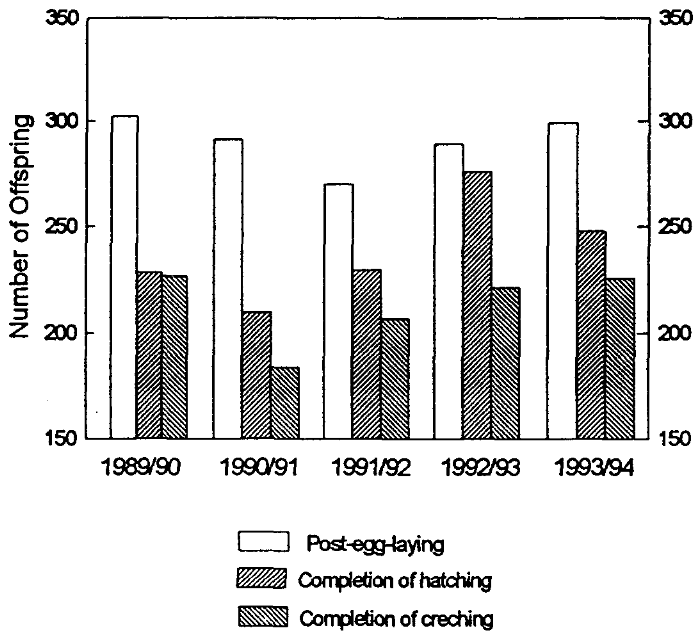


Figure 9.3 **Number of macaroni penguin offspring surviving to various stages of development (n=5) on Seal Island, 1989/90 through 1993/94. Data for post egg-laying was collected upon arrival at the field camp in December and therefore do not take into account early mortality that might have occurred between actual egg-laying and the census date. The post egg-laying censuses for 1989/90 and 1990/91 were conducted approximately ten days later than in the three following seasons, which underestimate the initial breeding population.**

10. Abundance and distribution of Antarctic fur seals in the northern South Shetland Islands, Antarctica; submitted by M.K. Schwartz, J.L. Bengtson, B.G. Walker, P.L. Boveng and R.S. Holt.

10.1 Objectives: Antarctic fur seal (*Arctocephalus gazella*) populations were exploited from the late 1700's through the mid-1800's. Severe depletion occurred in the South Shetland Islands, where the species was extinct until the late 1950's (recolonization was first noted at Cape Shirreff in 1959). Because the South Shetland Islands are important breeding and foraging sites for Antarctic fur seals, and thus significant in the recovery of this species, efforts have been made to monitor both their rate of recolonization and their spatial distribution. Four fur seal breeding colonies are known from recent surveys in the northern South Shetland Islands (i.e. Elephant Island vicinity), as described in Bengtson et al (1990) and Croll et al (1992). Two are on Elephant Island, Cape Lindsey and Cape Valentine (last censused in 1991/92); and two are in the Seal Island group (censused annually). The objectives of this survey were:

1. To count Antarctic fur seals at known breeding colonies,
2. To search for and identify newly-established or previously unknown fur seal colonies,
3. To resight tagged animals to better understand fur seal movements, and
4. To describe and report marine debris sighted on beaches or on animals.

10.2 Accomplishments:

Counts at Known Colonies: Surveys were conducted at Cape Valentine and at two islands off the northern point of Cape Lindsey, Elephant Island on 2 and 4 February 1994 (Figure 10.1). A survey at Large Leap Island (an informal name used by Seal Island personnel for an island 1 km north of Seal Island) was conducted on 15 January. Researchers were transported by Zodiac to fur seal breeding colonies which were surveyed from shore. Three counts of fur seal pups were conducted as the researchers walked the periphery of each colony. If any count differed by more than 10% from any other, a fourth count was made.

Antarctic fur seal colonies at Seal Island were surveyed daily as part of pinniped research at the Seal Island field camp (see report in this volume).

The maximum daily counts of live pups plus total dead pups observed at Seal Island colonies are shown in Table 10.1, as are the averages of the three (or four) counts obtained from the previously-known colonies at Elephant Island.

Newly-established or Previously Unknown Colonies: Portions of the coastlines of Elephant, Gibbs, Aspland and Eadie Islands, and the total coastline of Corwallis Island were searched with binoculars and the naked eye from a Zodiac on 2-4 February to document newly-established or previously unknown fur seal breeding colonies (Figure 10.1, Table 10.1). The areas searched at Elephant Island were the shores from Cape Lindsey, southwest to Smelly Point (Stinker Point), and from the point north of Cape Valentine to the southern shore of the bay about 2 n.mi. to the east. The north shores of Gibbs, Aspland, and Eadie Islands were searched. During Zodiac operations to support Seal Island research on 4 February, some of the small islands in the archipelago northwest of Seal Island were searched for new or unknown fur seal colonies.

One previously unknown colony was discovered on the south point of Cape Lindsey, Elephant Island, with 18 fur seal pups on 2 February. Two colonies were discovered in the Seal Island archipelago: one colony with 5 pups was found on the most northwesterly island; the second was found on an island 1 n.mi. northwest of Seal Island, comprising one group of 43 pups and another group of approximately 20 pups in an inaccessible cave.

Movements of Tagged Fur Seals: During the survey, eleven fur seals that were originally tagged at Seal Island (nine with orange All-Flex tags and two with metal Monel tags) were re-sighted. Eight of the tagged animals were seen on other islands in the Seal Island archipelago; two were seen at Cape Lindsey and one was seen at Cape Valentine.

Marine Debris: While conducting the fur seal surveys, researchers also recorded any marine debris of human origin. The marine debris recovered fell into three categories: (1) a portion of abandoned fishing net, (2) fishing floats, and (3) shipboard waste (soap bottles, bleach bottle, battery bottoms). The fishing net (stretch measurement of 11.5" x 11.5", cord thickness of 1/8", weight of 2.5 lbs, green in color, new condition, intact except where cut around the periphery) was recovered on the north side of Cape Lindsey. The material of this net was similar to a net removed from around the neck of a fur seal in 1992/93 on Seal Island.

10.3 Preliminary Conclusions: From 1991/92 to 1993/94 there was an increase of 10% in the pup counts at colonies that were counted in both surveys. Because the 1991/92 count also represented an increase of 18% over the 1986/87 counts, it seems clear that the Antarctic fur seal population remains in a state of growth in the northern South Shetland Islands. It must be noted, however, that there has been considerable variability in the dates of these surveys and that most of the counts (other than at Seal Island) have been conducted well after the expected period (late December to early January) for peak numbers of live pups. These counts, therefore, probably underestimate and may be more variable than the actual numbers of fur seal births (the most commonly used index of population size for fur seals).

10.4 Recommendations: This survey was a census to estimate abundance and trends of Antarctic fur seals breeding and foraging within the AMLR large-area survey grid. Because the results of the survey indicate that this population of fur seals continues to increase, regular efforts should be made to continue monitoring those colonies that are not visited as part of annual operations at Seal Island. The newly-discovered colonies in the Seal Island archipelago should be incorporated into annual efforts to census the colony at Large Leap

Island (usually done during Zodiac operations to re-supply the Seal Island camp). From the standpoint of accurately estimating the size of the breeding population of Antarctic fur seals in the northern South Shetland Islands, these surveys should be conducted as close as possible to the period of peak numbers of live pups (i.e., late December to early January, after completion of births but before substantial mortality occurs).

10.5 References:

Bengtson, J.L., L.M. Ferm, T.J. Harkonen, and B.S. Stewart. 1990. Abundance of Antarctic fur seals in the South Shetland Islands, Antarctica, during the 1986/87 austral summer. Pp. 265-270 in Antarctic Ecosystems, Ecological Change and Conservation. K. Kerry and G. Hempel (eds.). Springer-Verlag: Berlin.

Croll, D.A., J.L. Bengtson, R. Holt, D. Torres-N. 1992. Census of Antarctic fur seals colonies of the South Shetland Islands, 1991/92, Pp. 82-85 in AMLR 1991/92 field season report. J. Rosenberg and R. Hewitt (eds.).

Table 10.1 Numbers of live Antarctic fur seal pups counted at selected sites in the northern South Shetland Islands, Antarctica, during the 1993/94 austral summer. For comparison, numbers of pups counted at the same sites during austral summers of 1986/87 and 1991/92 are shown.

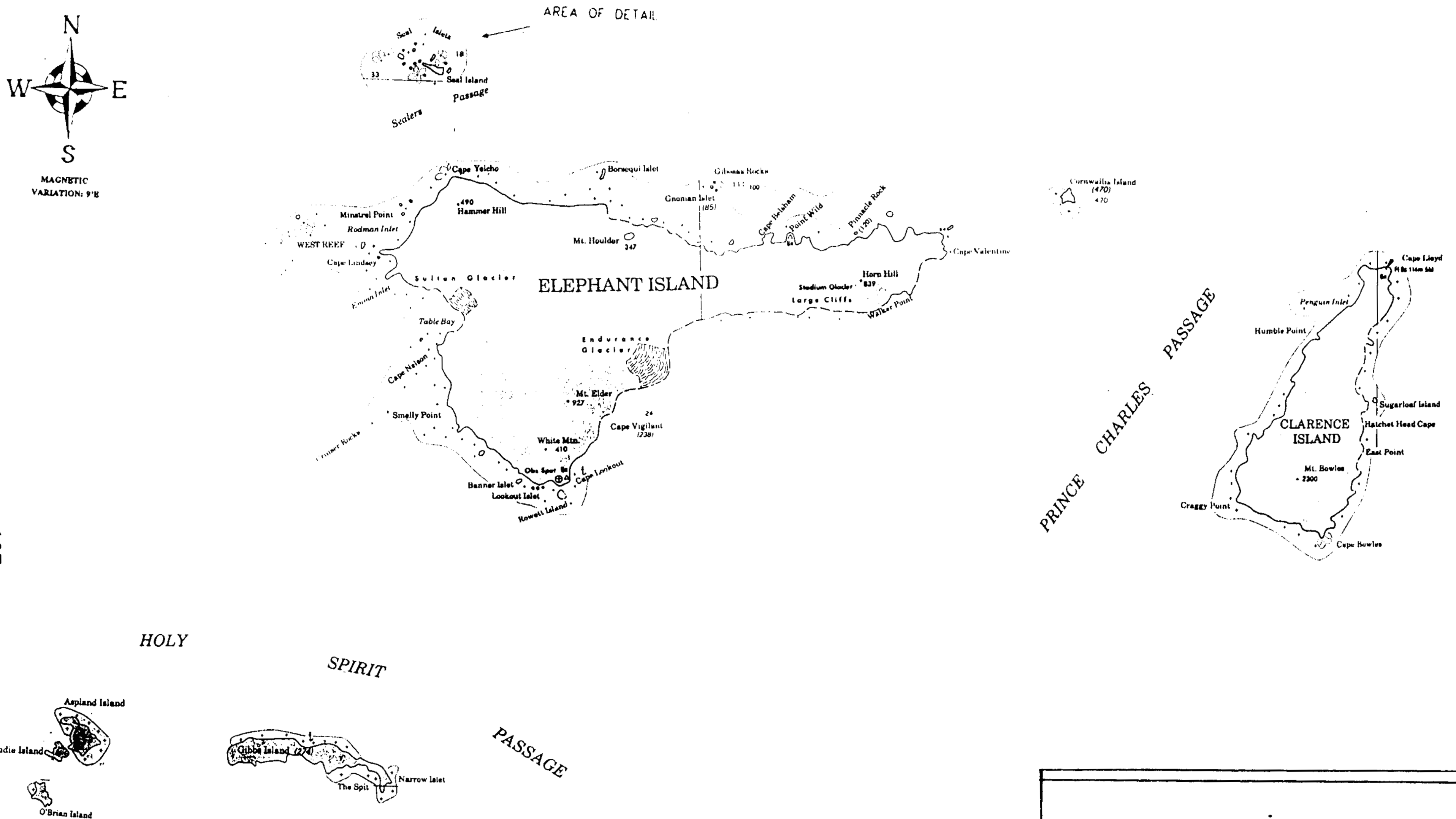
Location	1993/94	1991/92[1]	1986/87[2]
Elephant Island			
Cape Lindsey, northern island	267	227	203
Cape Lindsey, southern island	11	*	*
Cape Lindsey, south point	18	no count	no count
Cape Valentine	124	126	45
Seal Island archipelago			
Seal Island	299	300	249
Large Leap Island	304	258	275
Is. NW of Seal Island	68[3]	no count	no count
Total	1091	911	772

[1]Croll, D.A., J.L. Bengtson, R. Holt, D. Torres-N. 1992. Census of Antarctic fur seal colonies of the South Shetland Islands, 1991/92. Pp. 82-85 in AMLR 1991/92 field season report. J. Rosenberg and R. Hewitt. (eds).

[2]Bengtson, J.L., L.M. Ferm, T.J. Harkonen, and B.S. Stewart. 1990. Abundance of Antarctic fur seals in the South Shetland Islands, Antarctica, during the 1986/87 austral summer. Pp. 265-270 in Antarctic Ecosystems, Ecological Change and Conservation. K. Kerry and G. Hempel (eds.). Springer-Verlag:Berlin.

[3] Represents three sites: 43 and 5 pups, respectively, were counted at two sites; the third site, in a cave not accessible by Zodiac, was estimated to have about 20 pups.

*In 1986/87 and 1991/92, count at northern island off Cape Lindsey was combined with count at southern island.



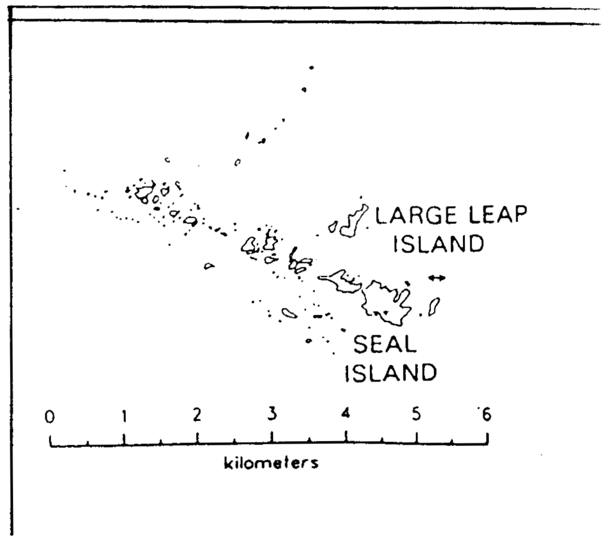


Figure 10.1 Chart of the fur seal survey region. Scale 1:200,000. Derived from DMA 29104.

11. Seabird research undertaken as part of the NMFS/AMLR ecosystem monitoring program at Palmer Station, 1993/94; submitted by William R. Fraser and Donna L. Patterson.

11.1 Objectives: Palmer Station is one of two sites on the Antarctic Peninsula where long term monitoring of seabird populations is being undertaken in support of U.S. participation in the CCAMLR Ecosystem Monitoring Program (CEMP). Our objectives during 1993/94, the seventh season of field work at Palmer Station on Adelie penguins (*Pygoscelis adeliae*), were:

1. To determine Adelie penguin breeding population size,
2. To determine Adelie penguin breeding success,
3. To obtain information on Adelie penguin diet composition and meal size,
4. To determine Adelie penguin chick weights at fledging,
5. To determine the amount of time breeding adult Adelie penguins need to procure food for their chicks,
6. To band a representative sample (1000 chicks) of the Adelie penguin chick population for future demographic studies, and
7. To determine adult Adelie penguin breeding chronology.

11.2 Accomplishments: Field work at Palmer Station was initiated on 8 October 1993 and terminated on 1 April 1994. The early start date was aided by joint funding from the National Science Foundation's (NSF) Office of Polar Programs. NSF recently chose Palmer Station as a Long Term Ecological Research (LTER) site, and it has committed long-term funding and logistics support to an ecosystem study in which Adelie penguins represent one of two key upper trophic level predators selected for research. As a result of this cooperative effort between the National Marine Fisheries Service (NMFS) and NSF, field season duration at Palmer Station now covers the entire 5-month Adelie penguin breeding season.

Breeding population size was determined by censusing the number of breeding pairs at 54 sample colonies during the peak egg-laying period (29 November). In 1993, these colonies contained 6165 pairs, a negligible decrease relative to the 6216 breeding pairs censused in 1992.

Breeding success was determined by following a 100-nest sample on Humble Island from clutch initiation to creche. Adelie penguins again exhibited high reproductive success in 1993, creching 1.60 chicks per pair, or 0.14 chicks more than they creched per pair in 1992. As in past seasons, two other indices of breeding success were also determined. The proportion of 1 and 2 chick broods was assessed at 49 sample colonies on 9 January. Of the

4155 broods censused, 62.1% (N=2578) contained two chicks, a slight increase over the 60.2% reported in 1992. Chick production was determined by censusing chicks on 23 January at 52 sample colonies when approximately 2/3 of them were in the creche stage. Production at these colonies totaled 6561 chicks, a 10.3% decrease over 1992 when 7319 chicks were censused.

Chick fledging weights were obtained between 6-23 February at beaches near the Humble Island rookery. Peak fledging occurred on 16 February, 3 days later than in 1992. Compared to 1992, the average fledgling weight of the 362 Adelie chicks sampled decreased by 200g (3.2 vs 3.0 kg). Data specific to the chronology of other breeding events are still under analysis and will be reported later.

As part of continued demographic studies, 1000 Adelie chicks were banded on 3 February at selected AMLR colonies on Humble Island. The presence of birds banded in previous seasons was also monitored during the entire field season on Humble Island as part of these studies.

Diet studies were initiated on 11 January and terminated on 18 February. During each of the 8 sampling periods, 5 adult Adelie penguins were captured and lavaged (stomach pumping using a water off-loading method) as they approached their colonies to feed chicks on Torgersen Island. All birds (N=40) were subsequently released unharmed. The resulting diet samples were processed at Palmer Station. A nearly complete absence of all prey other than krill (*Euphausia superba*) characterized the 1993/94 samples. These krill were larger than in previous seasons, averaging 40-50mm in length.

Radio receivers and automatic data loggers were deployed at the Humble Island rookery between 10 January and 15 February to monitor presence-absence data on 33 breeding Adelie penguins carrying small radio transmitters. These transmitters were glued to adult penguins feeding 10-14 day old chicks. Analysis of the data has not yet been accomplished due to the size of the databases obtained.

11.3 Tentative Conclusions: Adelie penguin breeding success was significantly higher during 1993/94 than it was during 1992/93 (1.60 vs. 1.46 chicks creched/pair), yet overall chick production at 52 sample colonies decreased by 10.3%, despite the fact that there was an insignificant decrease in the number of breeding pairs between these two seasons. Increasingly, the long-term data being accumulated at Palmer Station are suggesting that colony location relative to topographic features that influence winter snow deposition may be a key determinant of breeding success at the colony level. The somewhat anomalous condition suggested by the above data may result from the fact that the 100-nest sample used to determine per-pair productivity is not indicative of overall breeding conditions in the 52 colonies used to measure chick production. This would suggest that the number of chicks fledged per colony may in fact be the more significant data for determining year-to-year trends in Adelie penguin populations.

As last season, the predominant component in the diets of Adelie penguins was krill (*Euphausia superba*). However, unlike last season, more krill in the larger size classes dominated the diet samples (40-50mm vs. 30-40mm). This is consistent with LTER data on the pelagic distribution and size of krill between seasons (R. Ross, personal communication), and may be reflected in the slightly lower average fledging weights of chicks during 1993/94. More specific conclusions related to the interactions between diet, pelagic distribution of krill, fledging weights, and the duration of foraging trips are currently beyond the scope of this report due to the large size of the pertinent databases awaiting analysis.

11.4 Disposition of the Data: No diet samples were returned to the U.S. for analysis as all work was successfully completed at Palmer Station. All other data relevant to this season's research are currently on diskettes in our possession and will be made available to the Antarctic Ecosystems Research Group.

11.5 Problems, Suggestions and Recommendations: This season was generally free of problems at Palmer Station. Minor problems with the telemetry equipment were repaired on site, allowing this aspect of the research to achieve a potential comparable to last season. Early season problems with access to the rookeries due to wind and pack ice again made it impossible to implement Standard Method A6.2, Procedure C (chicks raised per colony) as specified in the CEMP manual.

12. Activities during the northbound transit.

(1) Marine mammal observations during the northbound transit; submitted by G. Alan Reitsch and Jennifer L. Quan.

The objectives of the marine mammal observations were to: (1) determine the relative abundance and distribution of marine mammals in the areas surveyed during transit; and (2) opportunistically collect identification photographs of humpback whales for population studies.

Marine mammal observations were conducted during the northbound transit from Punta Arenas, Chile to Seattle, Washington, U.S.A. These observations took place on the flying bridge of the NOAA Ship *Surveyor*. Effort began daily at 0600 and ended at 1800. Watches were maintained by a single dedicated observer. Two dedicated observers maintained watch during the transit from Punta Arenas to Valparaiso, Chile and during the Seabeam survey of the Canon de Chacao.

Observations during the northbound transit were divided into six transit segments: Punta Arenas to the vicinity of Isla Chiloe, Chile; the Seabeam survey of the Canon de Chacao (near Isla Chiloe); vicinity of Isla Chiloe to Valparaiso, Chile; Valparaiso, Chile to San Diego, California, USA; San Diego to location of geological survey off the Oregon/Washington coasts; and Oregon/Washington survey to Seattle, Washington, U.S.A. Although several survey projects were conducted during the transit, the Seabeam survey of Canon de Chacao was the only project with a survey protocol conducive to marine mammal observations.

Marine mammal species, behavior, and number were recorded when animals were observed within a 180° arc forward of the ship. Additionally, a five-minute scan (using 8X magnification binoculars) was conducted every twenty minutes and covered an area out to four kilometers. Marine mammal sightings were recorded in a time-event recording program on a laptop computer (Tandy 102). Using data provided by the ship's data logging system, latitude, longitude, time, depth, and sea surface salinity and temperature were recorded for the start of each five-minute marine mammal scan, marine mammal sightings, and the beginning and ending of observation effort. Environmental conditions (beaufort, sea state, swell, wind speed and direction, glare, and cloud cover) were also recorded to help define conditions affecting sighting ability.

Opportunistic photographs of baleen whales were taken in an effort to identify individuals. Unique pigmentation and scarring patterns on the underside of flukes, on the sides, and on the dorsal fin will be used for identification. Various 300mm camera lenses and 200 ISO film were used to provide desired resolution of whales at a distance.

Table 12.1 lists 20 different species of marine mammals that were sighted during the northbound transit (additional marine mammals were sighted while not on effort, but were not included in this report). The table also provides the amount of time spent observing for each transit segment.

(2) Seabird observations during the northbound transit; submitted by Larry Spear, Sophie Webb, and Mike Force.

The objective of northbound transit seabird observations was to increase an existing database for a study of distribution and density of seabirds along the coast of South America and offshore waters of the eastern Pacific. Seabird distribution as related to environmental features (including sea surface temperature and salinity, thermocline depth and profile, ocean depth, distance from land, and wind speed and direction) was the investigators' main interest.

Seabirds were censused during daylight hours when the ship was underway. Two people observed simultaneously, counting seabirds that came within a 90° quadrant and within 300m of one forequarter of the ship. Censuses were divided into half-hour transects. Total survey time was 220 hours, over an area of 2239.3 km^2 of ocean surface. Data on environmental variables were recorded on the bridge or were provided by the ship's survey department.

For this report, the transit has been divided into five regions. The first region was waters of the inside passage (IP) from Punta Arenas to a point where the ship entered the Pacific Ocean at about 42°S. From there to Valparaiso, Chile, the ship transited through the second region along the outer coast of Chile (OC). The rest of the cruise was through "offshore" waters greater than 200 miles (370 kilometers) from land. Within that area was the third region: the offshore Peru Current (PC) from Valparaiso to the Equator. The fourth region (also through offshore waters) was mostly tropical surface waters (TW), from the Equator to off the southern tip of Baja, California. The fifth region was off Baja, California (BC) to San Diego, USA. Hours of transect time and surface area surveyed (km^2) for the five regions were: IP, 25.0 hours, 254.7 km^2; OC, 31.6 hours, 331.6 km^2; PC, 76.0 hours, 789.8 km^2; TW, 72.8 hours, 728.7 km^2; and BC 14.7 hours, 134.5 km^2. Results from the northbound transit observations are reported in Table 12.2.

(3) Seabeam survey of Canon de Chacao; submitted by Jane Rosenberg.

At the request of Chile's Servicio Hidrográfico y Oceanográfico de la Armada (SHOA), a Seabeam survey of the Canon de Chacao was conducted. A representative from SHOA, Mr. Hernan Vergara, boarded *Surveyor* in Punta Arenas and disembarked the ship in Valparaiso, Chile. The general survey area was near Isla Chiloe, Chile, with the primary site of interest being the Canon de Chacao. Survey operations began on the morning of 21 March and were completed in the afternoon of 22 March. Using the ship's Seabeam system, the offshore canyon mouth was located and defined, and the canyon's deep water length was delineated. Also, a 3.5kHz echo-sounder was used to identify the sediment nature in the center of the canyon.

One-hundred percent coverage was not anticipated by SHOA. Areas of the canyon considered most important for surveying were indicated by Mr. Vergara. Boat sheets, preliminary plots, and other data from the survey area were taken by Mr. Vergara upon his departure from the ship. Data not removed by Mr. Vergara will be sent to the Ocean Mapping Center, Multibeam Support, Pacific Hydrographic Section, for final processing and forwarding to SHOA.

Table 12.1 **Northbound Transit Marine Mammal Sightings**

AREA	PUNTA ARENAS TO CHILOE TRANSIT	VENTS SURVEY OFF CHILOE	CHILOE TO VALPARAISO TRANSIT	VALPARAISO TO SAN DIEGO TRANSIT	SAN DIEGO TO US VENTS TRANSIT	US VENTS TO SEATTLE TRANSIT
EFFORT (hrs)	23:03	14:10	8:19	69:42	34:34	10:32
Balaenoptera physalus	0	0	0	0	2	0
Megaptera novaeangliae	0	0	0	0	11	0
Physeter macrocephalus	0	1	2	0	1	0
Balaenoptera edeni	0	0	0	2	0	0
Orcinus orca	0	0	0	0	2	0
G. macrorhynchus	0	0	0	57	0	0
Unidentified medium Cetacean	0	0	1	6	0	0
Unidentified large Cetacean	0	0	0	4	5	2
Unidentified small Cetacean	0	2	0	0	2	0
Unidentified Delphinid	0	0	7	589	14	0
L. obliquidens	0	0	0	0	2	8
Delphinus delphis	0	0	0	213	100	0
Tursiops truncatus	65	0	35	0	0	0
Grampus griseus	0	0	30	10	0	0
Stenella spp.	0	0	0	17	0	0
Stenella coeruleoalba	0	0	0	5	0	0
Stenella longirostris	0	0	0	50	0	0
Cephalorhynchus eutropia	2	0	0	0	0	0
Phocoena phocoena	0	0	0	0	2	0
Phocoenoides dalli	0	0	0	0	66	6
Callorhinus ursinus	0	0	0	0	13	7
Arctocephalus australis	77	0	0	0	0	0
Zalophus californianus	0	0	0	0	19	0
Otaria byronia	5	24	2	0	0	0
Unidentified Pinnipeds	68	12	0	0	7	1

Table 12.2 Species of birds seen by region and relative number. A = abundant, C = common, UC = regularly seen but not common, R = rare, dashed line = none seen. Abbreviations for regions are: IP = inside passage of Southern Chile, OC = outer coast of Chile, PC = offshore Peru Current, TW = Tropical surface waters, and BC = waters off Baja California.

	IP	OC	PC	TW	BC
Magellanic Penguin _Spheniscus magellanicus_	A	UC	--	--	--
Royal Albatross _Diomedia epomophora_	--	UC	--	--	--
Wandering Albatross _Diomedia exulans_	--	R	--	--	--
Black-browed Albatross _Diomedea melanophris_	A	A	--	--	--
Buller's Albatross _Diomedia bulleri_	--	UC	--	--	--
Salvin's Albatross _Diomedia cauta salvini_	R	A	--	--	--
Chatham Island Albatross _Diomedia cauta eremita_	--	UC	--	--	--
Southern Giant Petrel _Macronectes giganteus_	C	UC	--	--	--
Northern Giant Petrel _Macronectes halli_	--	R	--	--	--
Westland Petrel _Procellaria westlandica_	UC	--	--	--	--
White-chinned Petrel _Procellaria aequinoctialis_	C	A	--	--	--
Juan Fernandez Petrel _Pterodroma externa_	--	C	A	--	--
Dark-rumped Petrel _Pterodroma phaeopygia_	--	--	UC	UC	--
Kermadec Petrel _Pterodroma neglecta_	--	--	C	--	--
Tahiti Petrel _Pterodroma rostrata_	--	--	--	UC	--
Defilippe's Petrel _Pterodroma defilippiana_	--	C	A	--	--
Cook's Petrel _Pterodroma cooki_	--	--	--	UC	A
Stejneger's Petrel _Pterodroma longirostris_	--	A	--	--	--
Black-winged Petrel _Pterodroma nigripennis_	--	--	R	--	--
White-winged Petrel _Pterodroma leucoptera_	--	--	R	--	--
Sooty Shearwater _Puffinus griseus_	C	A	--	--	--
Pink-footed Shearwater _Puffinus creatopus_	UC	A	--	--	--

Table 12.2 (continued)

Buller's Shearwater *Puffinus bulleri*	R	C	--	--	--
Greater Shearwater *Puffinus gravis*	R	--	--	--	--
Wedge-tailed Shearwater *Puffinus pacificus*	--	--	UC	UC	--
Townsend's Shearwater *Puffinus auricularis*	--	--	--	UC	--
Audubon's Shearwater *Puffinus lherminieri*	--	--	UC	--	--
White-bellied Storm-Petrel *Fregetta grallaria*	--	UC	A	--	--
Wilson's Storm-Petrel *Oceanites oceanicus*	C	A	--	--	--
Leach's Storm-Petrel *Oceanodroma leucorhoa*	--	--	A	A	A
Band-rumped Strom-Petrel *Oceanodroma castro*	--	--	A	C	--
Wedge-rumped Strom-Petrel *Oceanodroma tethys*	--	--	A	C	--
Least Strom-Petrel *Oceanodroma microsoma*	--	--	--	R	R
Hornby's Storm-Petrel *Oceanodroma hornbyi*	--	R	--	--	--
Black Storm-Petrel *Oceanodroma melania*	--	--	--	R	UC
Markham's Storm-Petrel *Oceanodroma markhami*	--	--	A	R	--
White-faced Strom-Petrel *Pelagodroma marina*	--	R	C	--	--
Magellan Diving-Petrel *Pelicanoides magellani*	C	UC	--	--	--
Red-billed Tropicbird *Phatheon aethereus*	--	--	C	UC	--
Masked Boobie *Sula dactylatra*	--	--	C	--	--
Red-footed Boobie *Sula sula*	--	--	--	UC	--
Brown Boobie *Sula leucogaster*	--	--	--	UC	--
Peruvian Boobie *Sula variegata*	--	R	--	--	--
Imperial Shag *Phalacrocorax atriceps*	C	C	--	--	--
Olivaceous Cormorant *Phalacrocorax olivaceus*	--	R	--	--	--
Rock Shag *Phalacrocorax magellanicus*	UC	--	--	--	--
Magnificent Frigatebird *Fregata magnificens*	--	--	R	--	--
Great Frigatebird *Fregata minor*	--	--	--	R	--
Northern Phalarope *Phalaropus lobatus*	--	--	--	R	--

Table 12.2 (continued)

Red Phalarope Phalaropus fulicarius	--	C	R	UC	A
South Polar Skua Catharacta maccormicki	--	--	R	--	--
Chilean Skua Catharacta chilensis	C	C	--	--	--
Pomarine Jaeger Stercorarius pomarinus	--	--	UC	--	--
Parasitic Jaeger Stercorarius parasiticus	R	R	--	--	--
Long-tailed Jaeger Stercorarius longicaudus	--	UC	--	--	--
Kelp Gull Larus dominicanus	UC	R	--	--	--
Franklin's Gull Larus pipixcan	UC	R	--	--	--
Sabine's Gull Larus sabini	--	--	R	--	UC
Brown-hooded Gull Larus maculipennis	--	R	--	--	--
Sooty Tern Sterna fuscata	--	--	UC	--	--
Arctic Tern Sterna paradisaea	--	R	--	--	--
South American Tern Sterna hirundinacea	R	UC	--	--	--

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We relied heavily on each of the ship's departments. The deck department helped us deploy our sampling equipment, set up and repair our gear, and stow our cargo. The electronic technicians helped us keep our equipment operating and assured that the CTD/rosette worked flawlessly throughout both legs of the cruise. Due to the efforts of the engineering department, virtually no ship time was lost to mechanical failures or electrical power outages. The survey department helped us with all phases of our sampling program, ran salinity checks, and managed to get a bit of Seabeam work done in between. The stewards worked a crowded and frequently chaotic wardroom with adeptness and grace. The officers provided us with unflagging professionalism and cooperation and always operated the ship in a safe manner.

Even more impressive is the hospitality that we have come to enjoy when working aboard *Surveyor*. The can-do attitude of the officers and crew and the ship's friendly atmosphere make *Surveyor* unique among research vessels.

One individual deserves special recognition: LT John Lowell. As *Surveyor's* Field Operations Officer, he guided the ship's personnel with finesse and ingenuity in accomplishing all our research objectives. We were continually impressed by his attention to detail and untiring patience. In particular, the remodeled plot room, the new clean power supply, the new CTD winch, and the hull-mounted transducers vastly improved the efficiency of our operations.